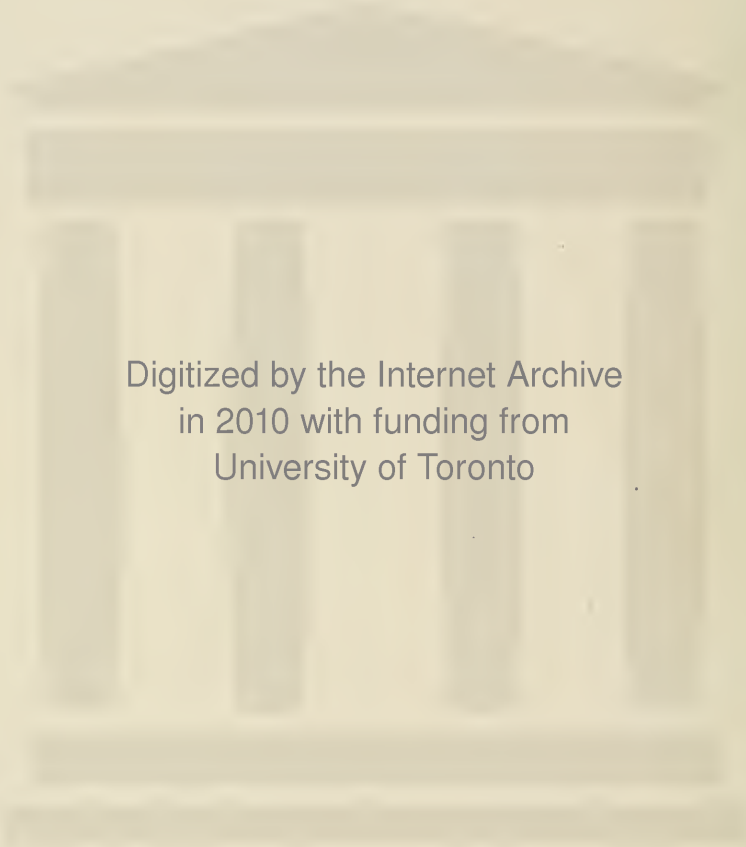


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Chemical Engineering Progress

TRANSACTIONS
OF THE
AMERICAN INSTITUTE
OF
CHEMICAL ENGINEERS

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CHEMICAL ENGINEERS

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TRANSACTIONS OF THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

OUR RESOURCES

By President G. W. THOMPSON

Read at the St. Louis Meeting, Dec. 15, 1917

When we speak of resources we usually have in mind material things, such as financial resources, mineral resources, agricultural resources, etc. It would appear, however, that this is a rather limited construction of the meaning of the word "resources," for with all of these material resources there is the presupposition that one has the ability to use them. Wealth owned by an idiot may not be to him a resource, but rather a liability. A mining deposit that no one knows how to work is hardly worth calling a resource. Wonderfully fertile fields in the center of Africa are not resources, to the extent that they are removed from the intelligent use of civilized men. In our own country it is true that wealth, mineral deposits, and fertile fields are resources, but they are such because there are resourceful men in our country who can use them. If the present war teaches us anything, it is this: In these days wars cannot be won because a nation has great material resources only, but rather because a nation has resourceful men.

Let us consider this carefully and see whether what I have said is true and what, if it is true, it implies. Mexico is a country that is wonderfully rich in possibilities. Unfortunately for Mexico, whatever the cause may be, the Mexicans have not, themselves, so far developed their possible resources to their country's full advantage. In so far as these resources have been well developed, it has been because resourceful men have gone to Mexico and endeavored to turn mineral and agricultural resources to profitable ends.

The mechanical ability of the citizen of the United States has been recognized all over the world. Give him a mechanical problem and it is not long before that problem is solved. His agricultural machinery, his machines for the manufacturing of food products, his machines for the stamping and molding of metal, his machines for the utilization of electrical energy, and hundreds of other kinds of machines are evidences of the wonderful mechanical resourcefulness of our citizens.

It should be born in mind, however, that the mechanical engineer's peculiar field lies in the taking of materials and turning them into machines. The materials must be furnished to him. On whom, then, does this furnishing of materials to the mechanical engineer mostly depend? I think it will be admitted that the furnishing of materials depends mostly upon the chemist. All of our smelting operations are highly developed chemical manufacturing processes. After metals have been won they must be combined together and with non-metallic elements, in order that they shall be serviceable to the mechanical engineer. Agriculture is a chemical process, and agricultural products must be treated or prepared chemically before they can be used to the best advantage. It may be that it is not as generally recognized as it should be that all smelting and agricultural operations are chemical operations—nevertheless, we as chemists perceive this truth as a reality.

We see, therefore, that machines cannot be made unless the materials needed for them have been provided, and we also see that the production of raw and semi-raw materials depends, to a great extent, upon the resourcefulness of the chemist. Whatever the material resources of a country may be, these resources cannot be made fully effective unless efficient chemical processes for their utilization have been worked out.

I must say a few words here, lest I be misunderstood and be thought to be claiming too much for the chemist. In the development of a process for the production of the chemical elements or compounds, the chemist is essential. To make these products on a commercial scale, the mechanical engineer or his equivalent is also necessary. By the equivalent of the mechanical engineer we mean the person who knows how to apply material forces to machines and appliances so as to obtain effective results, and one also who knows how to construct these machines. The person who knows chemistry and chemical processes adequately and who

also has a broad knowledge of the field of mechanical engineering, constitutes that modern product of which each of the members of our Institute is a representative—the Chemical Engineer.

Analysis and synthesis, to a certain extent, parallel each other. In analysis we seek to know the ultimate composition of substances, that is—the elements they contain. Having this information, we then seek to know how these elements are chemically combined, i.e., the constitution of the chemical compounds present. There are, therefore, two limits which confront the analyst. In making an ultimate analysis he cannot go beyond the elements themselves. He cannot decompose them into other constituents. The time may come when he will be able to do this, but the prospects are that that time is a long way off. The other limit lies in his determination of the constitution of chemical compounds. This is not a fixed limit, and the information we are obtaining every day is shoving this limit further back and widening the chemist's horizon. So, too, with the synthesist. He has the same fixed limit as the analyst. He cannot combine substances to produce elements, and he has a similarly continually widening limit as to the compounds that he can synthesize. He is adding continually to the superstructure which rests upon analysis.

The materials which a country needs may be obtained from its material resources in four ways, in all of which ways the chemist is pre-eminently the active factor.

First, by the production of commercially-pure elements from minerals. Such production being by methods which may with propriety be called analytical. In this way lead, silver, copper, etc., are obtained.

Second, by the production of such chemical compounds as are found in mineral deposits or in plant and animal bodies. These compounds are isolated by methods that are also essentially analytical. In this way common salt, cane sugar, glycerine, etc., are obtained.

Third, by the production by synthetical methods, of such chemical compounds as are referred to in class two. In this way indigo has been produced.

Fourth, by the production by synthetical methods of compounds not produced by nature, i.e., not found in mineral deposits or in plant and animal bodies. In this way innumerable inorganic compounds, such as the salts of the heavy metals, and many inor-

ganic compounds, such as the so-called coal-tar dyes, have been obtained.

It is not to be assumed that these are the only ways in which the chemist is the active factor in the production of useful materials, but the four classes of materials given serve as a basis for the systematic study of Our Resources.

We will attempt now to review, in as general and condensed a way as possible, some of the resources of our country and the relation of the chemist to them, what he has done, what he apparently will be unable to do, and what we may hope for him in the future. Considering the chemical elements which are included in Class One, it is quite evident that we have a reasonably ample supply of the minerals which contain the following elements; Aluminum, arsenic, barium, boron, calcium, copper, carbon, iron, lead, magnesium, phosphorus, silver, sodium, titanium, and zinc. It is true that under pre-war conditions some of these elements, or the minerals containing them, were imported, but they were all produced in this country and the amount imported was insignificant as compared with home production. Elements such as arsenic, barium, calcium, magnesium, phosphorus, and sodium were mostly used in chemical compounds. Arsenic was produced mostly as a by-product of smelting operations, in the form of white arsenic. Barium was produced mostly as mineral barium sulphate or barite. Calcium and magnesium were produced to some extent as metals, but were mostly in the form of chemical compounds. Phosphorus was produced to some extent as an element, but was mostly used in fertilizers as acid phosphates. Sodium was produced in large quantities in the metallic form, but was mostly used in chemical compounds such as caustic soda and sodium carbonate. The modern chemist gave us methods of producing aluminum, magnesium, phosphorus, and sodium. The modern chemist has developed practically all of the metallurgical processes on which the production of copper, gold, iron, lead, silver, and zinc rests. He gave us the electrolytic refining of copper, the cyanide process for the recovery of gold, the structural knowledge of steel, the Bessemer and Open-hearth processes for making steel, processes for the electrolytic refining of lead, and processes for the electrolytic production of zinc. All of these contributions of the chemist have greatly increased the output of these elements and rendered them more available for useful purposes. It is obvious, of course, that

we have an ample supply of such elements as chlorine, hydrogen, nitrogen, oxygen, and silicon, all of which the chemist uses in the production of chemical compounds.

For some years before the war the production of bromine was a profitable industry, in spite of the unfair competitive conditions under which it labored.

In the case of carbon, we have an ample supply, although in its allotropic forms, graphite and diamond, we have not all of the supplies that could be desired. The chemist, however, has given us an artificial graphite which, to a great extent, has supplied our needs for this material, and he has also given us abrasive compounds that approach the diamond in hardness. With regard to all of these elements, the chemist is continually contributing to their more economical production and use.

We must not neglect to mention sulphur, which, when converted to sulphuric acid, is the basis, practically, of all chemical industries. Although large quantities of pyrite have heretofore been imported, the importation of sulphur itself has fallen to a negligible amount, due to the production of sulphur by the methods developed by Frasch. It would appear also that the recovery of sulphur compounds from smelter gases would, under normal conditions, more than supply our needs, taken together with our other sources of production. At the present time the supply of sulphuric acid may be considered as inadequate, but this is due only to extraordinary demands created by the war, and it would seem probable that even those demands could be met satisfactorily at an early date.

There are some elements of which we have no appreciable supply. One conspicuous example is iodine. Practically the entire world's production of iodine comes from Chile, where iodine is obtained as a by-product of the nitrate industry. If the need were great enough, however, iodine could be obtained by the old-fashioned method—from seaweed.

Antimony has been very little produced in this country, probably due to economic reasons, although scattered deposits have been found and worked. If the need were great enough, undoubtedly, antimony could be produced. We are fortunate, however, in having a large quantity of antimony in the form of antimonial lead which is obtained as a by-product of the lead-smelting industry, antimonial lead being suitable for most purposes where antimony

and lead together are used. If the need came, there would be little trouble for the chemist to separate the antimony from the lead.

It is rather curious that there has not been a great quantity of manganese ores produced in this country. Just why this production has lagged is rather difficult to say with certainty. Manganese deposits exist and even if they are not of the particular grade desired, say, in the steel industry, their purification by chemical means is not difficult. The cheapness of manganese ores and recovered manganese obtained from abroad before the war was probably principally responsible for our undeveloped production here. It is true that a large quantity of manganese is obtained as a by-product from zinc ores in New Jersey, but that supplies but a small part of our needs. Should the importation of manganese ores and products be rendered more difficult, it would seem that the only way that the required amount of manganese could be obtained would be by the development of our own deposits and probably the calling in of the chemical engineer to develop methods of separation and purification.

We have no platinum deposits in our own country, but there are great quantities of platinum in the country in the form of jewelry, etc., that should be available for the war needs of our country.

We have no great deposits of nickel and cobalt and it would appear that we must depend, for some time at least, upon the Canadian supplies, it being very fortunate for us that we are on such friendly relations with our Canadian brothers.

Since the war began our lack of a supply of potassium salts has been manifest, not merely to us, but to Germany, the country from which our supplies mostly came. It is evident that this shortage must be met, and it can only be met by the help of the resourceful chemist. It is not due to the absence of potassium from our mineral deposits that we have not been able to supply ourselves, but it is due to the fact that before the war started, the production of potassium in this country was not developed as a commercial proposition. There are large quantities of potassium in our feldspar, in our alkaline lakes, and in various materials used for the production of Portland cement and beet sugar. There are great quantities of potassium in seaweeds. The production of potassium compounds must be developed. Our country must

be supplied, and it is up to the chemists to supply it. Considerable quantities have already been supplied and larger supplies may be expected.

We have no tin deposits of great value in this country, although tin is a widely distributed element, especially in the southeastern states. There seems to be no probability that the chemist will be able to do very much in the near future in the way of giving us a supply of tin ore. He has, however, been of invaluable assistance in the development of processes for the recovery of tin from tin scrap, and it would seem as if at some time in the future, when the stress is sufficiently great, methods will be developed for the collection of much larger quantities of used tin articles and their treatment by detinning processes whereby this semi-precious metal will be recovered.

There are many other elements, more or less rare, to which I could refer. What we have endeavored to show so far is that with regard to most of the elements the chemist has been an important factor in their production, and that the chemist promises, with some few exceptions, to be a still more important factor in the future.

We now come to Class Two, which are those chemical compounds as are found in mineral deposits or in plant or animal bodies. It would be convenient for us, however, to consider Class Three in connection with Class Two. In Class Three we have those chemical compounds as are referred to in Class Two, which have been produced by synthetical methods. With very few exceptions, the inorganic compounds included in Class Two, where the need has arisen, have been synthesized and appear in Class Three. It is true that certain minerals have not been synthesized in the physical form corresponding to the mineral, thus asbestos is mined as a mineral product and there has been no demand for the production of anything similar to asbestos, by a synthetic method, as the supply, which mostly comes from Canada, has been reasonably ample.

So too with cryolite used in the electrolytic manufacture of aluminum. It is imported almost entirely.

It is when we come to organic compounds that the significance of our classification becomes more striking, and the chemist must admit that, while great progress has been made in the knowledge of the constitution of organic compounds found in nature, the

development of their commercial production synthetically has not made as great a progress as could be desired. It is true that some of the natural dye stuffs, such as indigo, have been produced synthetically, but there still remains a very large yield which is unworked. It seems probable that the lack of progress in this direction has been due to the abundance of our supplies. Our country has had ample quantities of sugar, starch, turpentine, oils, and fats, and hydro-carbons for its needs. It has been easier to produce these things by depending upon "mother nature" than it has been to work out synthetic processes. There need be no criticism of the chemist for this fact, but in the stress of war it is brought home to us how desirable it would have been if certain arts had been developed from our synthetic knowledge, that would be available in our present struggle. There are certain things which we do not produce in appreciable quantities, such as shellac, rubber, and the fossil gums. Rubber has been produced synthetically, but, for some mysterious reason, when the methods were announced, the supply of rubber from natural sources became so great that the production of synthetic rubber was rendered unattractive commercially, if for no other reason.

During the war the demand for glycerine has become very great. Some day a commercially profitable method for synthesizing glycerine will be developed. Perhaps we have learned our lesson so well that that day is nearer at hand than we dare hope. Let it not be supposed, however, that the chemist has not been active in these two important fields. While he has not developed, commercially, processes that actually synthesize many organic compounds of commercial value and produced by nature, the chemist has transformed many chemical substances into compounds of greater commercial value. The chemist has converted various oils into edible products. He has also, by hydrogenation, changed liquid oils to solid fats, bringing about a much closer parity in price between oils and fats of various origins. He has developed methods for more cheaply producing alcohol and acetic acid. He has produced sugars from starch. He has produced synthetic resins, which, to some extent at least, have replaced shellac and the fossil gums. He has produced rubber substitutes which have at least the merit of having kept down to some extent the price of genuine rubber goods. He has developed methods for the recovery of rubber from waste products. He has converted mineral oil into

satisfactory substitutes for turpentine. He has continually added to the yield of these natural and other products, by the study of the natural processes by which they are elaborated.

We must not neglect to mention the most important compound found in nature, of which we have no natural supply. I refer to the nitrates. We have no nitrate deposits, but in that respect we are not less favored than most other nations. The nitrate supplies of the world, for a great many years, have come from one part of the west coast of South America. Germany was one of the first countries to realize its deficiency in this respect, and Germany bent its best efforts towards producing nitrates synthetically. At first her supply of synthetic nitrates was developed in Norway, where great water-power resources existed. Later, to make herself more self-contained, she developed other processes, so that to-day she is practically independent of South America and Norway. Without discussing the merits of any particular process for producing nitrates, it is apparent to us that it will not be long before our country has adequate supplies. Partly, it may be by processes originally developed in this country, involving the direct combination of nitrogen with oxygen, and partly by other processes involving first the production of ammonia and then its oxidation. It seems probable that next to sulphuric acid, nitric acid is the most important chemical needed in the development of our industries, and we should look forward to the much delayed time when nitrogen compounds will become more available.

It is in Class Four, however, that the chemist has been so conspicuously effective, for in Class Four, we have those compounds which are not found in minerals or in plant or animal bodies, but are essentially artificial compounds. Here we could fill a long list, if we were permitted, of the inorganic compounds alone that the chemist has produced from every one of the elements by combining it with others. If we attempted to list the organic compounds produced, the list would probably be longer than that of the inorganic compounds. So far these purely synthetic compounds have not shown themselves to possess food values, but as decorative materials, as preservatives, and as medicinals their use has been very great. In the dye industry the artificial dyes have largely displaced natural dyes.

Considering the foregoing as a description of the four classes of materials which constitute the material resources of our country,

a very proper criticism could be made that this account is very crude and inadequate. It serves, however, the purpose I have had in mind and which I have already outlined as illustrating the relation of the chemist to our resources, and it serves also as a preface to certain other very important considerations which I will now attempt to outline.

During the present war many processes have been developed in this country for the purpose of increasing our supply of needful materials. Many of these processes have been developed into successful commercial form. Arts have been established.

I think every one who has been instrumental in developing these arts, and many others also have asked themselves what is to become of these arts when the war is over. Are these arts, due to foreign competition, to become extinct and lost as it were, or will they be able to stand on their own feet in face of that competition? The answers to these questions will vary according to the arts. Some have, undoubtedly, become firmly established and will withstand foreign competition. Others, undoubtedly, will tend to become lost arts, and this tendency should be considered as most unfortunate. Now is the time to study this question and to be prepared to meet it when the war is over; meet it if need be by allowing the arts to perish, or, if it is more desirable to maintain the arts, by appropriate methods of procedure.

Let us consider this by way of illustration. As indicated above, the production of potash in this country is not to-day equal to the demands of our country. It would seem probable that when the war is over, if Germany follows its old practice of unfair competition, the potash industry will have to cease operations. Potash can be produced in Germany and sold here probably cheaper than we can make it in the near future. A great deal of money has been expended in the development of the art of producing potash in this country. Shall we allow that art to become extinct?

Our government has prepared for the expenditure of a large sum of money for the fixation of nitrogen and the production of nitrates. It can hardly be expected that when the war is over and the demand for nitrates falls off, that immediately the processes and arts which have been developed will be able to withstand the competition of Chile. Nitrates can be produced in Chile at a figure which will probably be lower than what they will be produced for

in our government plants when the war is over, unless the war lasts for a long time.

Artificial rubber has never been manufactured in this country. Chemical processes involving its production synthetically may be known. The war has created a great demand for rubber. Should the war last long enough, it might be profitable to develop the production of synthetic rubber, and after the war the art would find difficulty in living.

This prospect of any art perishing in our country is not a pleasing one to me, because it involves a loss of resourcefulness which to me is of more importance than a loss of resources.

The examples I have referred to are by no means the best examples that could be selected. Each of you can probably suggest a better example. They serve our purposes, however, and indicate our needs. They present to us a problem which deserves very careful consideration. Many solutions of the problem can be offered. Undoubtedly, in the case of nitrates, the production can be continued even at a loss after the war is over, provided sufficient pressure is brought to bear upon our legislators.

In the case of potash the problem is somewhat different. Such production is to-day in private hands, and it would appear unreasonable to expect private capital to continue for any length of time to operate a losing or unprofitable business. Undoubtedly, after the war is over, more potash will be produced at a profit in this country than there was produced before the war, but the amount will be insignificant. I hold no brief for any potash manufacturer and do not know, directly or indirectly, any one engaged in such manufacture. Therefore what I have to say is entirely disinterested. We have to-day government controlled industries. This government control of industries is a war measure. I would hesitate to advocate any control of industries, in general, in times of peace, but wherever there is a case like the potash industry, which is very important to the life and progress of our nation, it seems to me that we have a special case involving special forms of treatment and consideration. It is not very desirable now that any branch of the potash industry be made a government controlled industry, but when peace comes it seems desirable that some, at least, of the potash industries be put under government control, so that the arts so far developed will be maintained and further development provided for. I believe that the potash industry

should be controlled and subsidized, the expense of the subsidy perhaps being met by a very small tax upon imported potash.

In the case of artificial rubber, it would seem that the rubber manufacturers could afford to organize an institute which would be profitable to all the manufacturers and be for the purpose of developing methods for the production of artificial rubber and allied products. It seems that here government assistance should not be necessary as in the case of potash. The rubber manufacturers should, if practicable, establish an art which could be controlled by patents, each of the rubber manufacturers deriving proportional benefit.

What we have suggested with reference to the nitrate, potash, and rubber industries, should be considered only as types. Perhaps there are other products in regard to which a method of treatment could be developed similar to that suggested in these three cases.

What I have endeavored in this paper to indicate is this: It is not sufficient for us to consider simply what our resources may be, but we should also consider how our resourcefulness can be developed. Undoubtedly much can be done by the education and employment of more chemists and the better education of each chemist. Much can be done by the broader and more intelligent education of chemical engineers, but there still remains the problem of maintaining such arts as have been developed during the war, and the further development of the new and old arts which are now successfully practiced. In some cases I firmly believe that the maintenance of these new arts and the development of other newer arts cannot be accomplished unless there is a broader conception of the advantages of community action based upon community interests.

REPORT OF THE COMMITTEE ON CHEMICAL ENGINEERING EDUCATION

Read at the Buffalo Meeting, June 20, 1917

THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS,

GENTLEMEN: Immediately following the New York meeting in January, the Chairman of your Committee, in conference, took up with Dr. Mann of the Carnegie Foundation for the Advancement of Teaching, the matter of distribution among our members of the final findings of the Foundation as a result of its two years study of Engineering Education, and also the matter of the joint meeting of engineering societies to which we agreed at our Cleveland meeting. It was tentatively planned with Dr. Mann that he should mail a copy of the final report of the Carnegie Foundation to such members of the American Institute of Chemical Engineers as request it by card mailed to them for indication that they desire to receive it. Before the final report is issued it was Dr. Mann's plan to send details of the report from time to time to the members of the Advisory Committee of which the Chairman of your Committee is a member, as these details come from the press. One-half of it was then in the hands of the printer and the rest was expected to be finished shortly.

In the discussion it was brought out that Dr. Mann has many suggestions to make in the matter of curriculum and that he expects to be able, by a recorrelation of the work in the engineering schools, to reduce the number of hours to 15 credit hours and still keep the course within four years. He expects to interest the professors of science, such as physics, and particularly mathematics, to allow most of the elementary material to be given in connection with the applications and than later in the course the mathematics professor, for instance, would take these students and polish up from a mathematical point of view the mathematics which was thus learned.

The Carnegie Foundation plans to hold its joint meeting with the engineering societies after the report in its final form has been

placed in the hands of the members of the different institutes, including our own.

The delay in getting to this stage, Dr. Mann states, has been due to the change of point of view by the profession. It has been rather elusive to attempt to discover, through the medium of the opinion of the engineering profession, what the real demand upon engineering education was. The matter of the whole Carnegie report was planned for discussion before the Society for the Promotion of Engineering Education at its meeting at Northwestern University, June 27-29, 1917, where practically the whole meeting was to be devoted to this subject and where a large attendance of university professors was to be urged.

Only a few weeks subsequent to this conference with Dr. Mann, saw the initiation of the rapid steps which brought the country into war. Most of us held student excitement in check and insisted upon a full rounding out of the courses, particularly of engineering and chemistry students and discouraged even enlistment in the Officers' Reserve Training Camps on the ground that the Government would need all the engineers and chemists it could get for production of munitions and other non-military war purposes. It was not likely that this Government would make the mistake made by Britain and Germany of sending its chemists to the firing line. Nevertheless, many students frankly feared such governmental lack of foresight and went into the Officers' Camps while the opportunity existed. Others were graduated to work at once in the Civil Service arsenals, munitions and chemical plants. Next year as a result of the draft and other reasons there will be a considerable falling off of students. In addition, the government is already drafting the time and services of many professors in our technical schools and this will probably increase. We are all anxious to help where our knowledge and experience will count most against Germany, and a number of individuals and institutions have sought the advice of the military and other branches of the Government as to their best avenue of service.

As a result of this whole situation, educational matters are unsettled. The Carnegie report has not been issued. The Society for the Promotion of Engineering Education will not meet at Northwestern University in June, as planned, to discuss the Carnegie Report, but at the invitation of the Advisory Commission of the National Council for Defense, it will meet in Washington in July

to formulate recommendations to the Engineering Schools to advise them how to temporarily change curricula to render most efficient war service, by suitable education of engineering students.

It is a pity that all this Chemical Engineering education work is to be interrupted, for, besides the normal efforts in behalf of sound chemical engineering education which are being made without any special publicity by a number of institutions, there are indications of greater and greater interest in the work as its importance grows upon the attention of educators. There is a slowly growing list of institutions who are adding a curriculum in chemical engineering to their work. There are also notable changes in point of view in administration of such work, especially in the recognition of chemical engineering as something else than a mere off-shoot of a chemical department. There are also some notable innovations in methods of teaching industrial chemistry and chemical engineering at several institutions. In this connection, mention should be made of Columbia University, Massachusetts Institute of Technology, University of Cincinnati and Lafayette College. The omission of others has only the significance that they have not been called to our attention or they are quietly carrying on the good work without novel experimentation or publicity. The mention of these names in the absence of any adequate survey of these and other institutions will serve, however, as healthy signs of progress and to indicate the thought that is being given to the matter by educational institutions.

In view of the fact that the United States Government is preparing for active war campaigns of three years minimum duration, many of our university and engineering students will be required as officers. It is the duty of all educational institutions, therefore, to recognize this and give the men in addition to the usual fundamental training, any special preparation for war which is possible to arrange for them.

Personal conferences with officers of U. S. Army Engineers' Corps develops that such help may be of two kinds as far as chemical engineers are concerned:

1. Field work and the practical side of such military engineering topics as military topography, pontoon bridging, spar bridge erection, trenching, approach construction and other field fortification work. The object of the above is largely to emphasize the importance of *speed* as a differentiating feature between the eco-

nomics of military engineering and other branches of engineering. This work can be carried out by the civil engineering instructors from the Army Engineers Field Manual.

2. Special topics such as chemistry, manufacture, specifications and testing or control of military explosives and munitions.

Your committee therefore recommends:

I. That this Institute recommends to those in charge of chemical engineering courses that for the duration of the war, all students of chemical engineering be given practical field work in military engineering such as military topography, pontoon bridging, spar bridge erection, trenching, approach construction and other field fortification work in addition to or in place of convenient portions of the regular curriculum to the extent of three clock hours per week.

II. That detail work be introduced as far as possible in the laboratories and class rooms on the chemistry, manufacture, testing and control of military explosives and munitions manufacture.

Respectfully submitted,

JAMES R. WITHROW, Chairman,

A. D. LITTLE.

June 20, 1917.

The CHAIRMAN: You have heard this interesting report from the Committee on Chemical Engineering Education. Is there any discussion?

Mr. HARRY O. CHUTE: It does not seem to me that it will aid any to instruct the chemical engineer in mechanical engineering as applied to military subjects. For example, a chemical engineer may not be able to build a pontoon bridge, but in the United States there are many civil and mechanical engineers as compared to the chemical engineers, and we will feel greater need for chemical engineers in chemical works than we will for engineer officers of the army whose work is largely mechanical, and it seems to me that the chemist in this war should confine himself to the production of munitions of war, medicines and sanitary work and things that are more closely allied to chemistry than those things which are allied to mechanical engineering. The officers of the army, I regret to state, do not seem to see any place where the chemist fits into military affairs, the reason being that the chemist's duty is not so much at the front as it is serving behind the lines. Therefore, I would suggest that the recommendation: That chemical engineering

students be given instruction in such things as pontoon bridge building and other mechanical engineering features be eliminated from the report.

Dr. JAMES R. WITHROW: Mr. Chairman, I, of course, object to this recommendation on several grounds. The statements made are not strictly accurate. Great Britain and France are using a great many thousands of chemists and chemical engineers in the trenches of France as chemists, and I wish that I could go more into detail about that. I have been at repeated conferences during the past year with army officers and others, and it was really often that they are very highly pleased with the chemist's work; in fact, I understand it has been in the newspapers that General Haig has publicly commended and praised the work of the civilian chemists at the front. That is probably the only public notice anywhere that chemists were actually doing anything. It has been necessary for the chemists to be at the front; it is not necessary to state the reasons for that; many of them are well known; many of them are not well known; and these chemists find themselves woefully handicapped at the start because they had no training as to the general military arrangement or plans of any kind. It would be sufficient objection to the previous speaker to merely state that anyone can see that, that students busily occupied with other studies, except three hours a week, are not going to be made military engineers of pontoon bridging, etc.; they are not going to be experts at all; they are going to be given an introduction to what the situation is so that they will not make ridiculous recommendations to the army engineers, because of inability to see just where the chemist fits in in many cases. We should do something. If this Institute does not do it others are going to do it anyway, and I would suggest this Institute do it.

Dr. CHARLES S. PALMER: I make a motion that this report be accepted and that the committee be continued in office and leave the committee to work it out.

The motion was duly seconded and carried.

The CHAIRMAN: Dr. Olsen would like to ask a question.

The SECRETARY: I would like to ask whether Prof. Withrow has anything authoritative from the Army with reference to the drafting of chemical students or chemists. Has the Government a fixed policy on that?

Dr. JAMES R. WITHROW: I am sorry to say I cannot say anything

about that, because it is very difficult to secure information that you can depend upon. I have heard a major in the United States Army whose point of view I have learned from conversations and conferences and hearing him speak, say they recognized the importance of everything Mr. Chute mentioned and the necessity of using these men in production. I have heard of his being contradicted by an officer of the United States Army of higher rank, saying that when the last provision was being made, chemists were not included in the exemption. I can hardly believe that is true; nevertheless, it may be true; and the consequence has been that I have advised our chemical engineers when they have asked me not to go to training camps. All those boys had two years military training. We have something like 2000 men under arms all the time, and of course they were anxious to be admitted into the officers reserve corps. They were eminently competent for that work if they were physically fit; they were anxious to get in there—I advised them not to do it, because while they would be missing their chance to become officers, yet it was more patriotic to the country to wait until this chemical need comes up. However, I have seen printed statements within the past three weeks that the Ordnance Department has on file so many applications from chemists and chemical engineers for their branch of the service that they saw fit to print a statement that no more applications would be received, except for mere filing in case of a remote future contingency. In other words, the chemists and chemical engineers of the country have volunteered for all branches of the service where it was obvious a chemist could be used so much that the Government has been embarrassed by these volunteers, so that the Government is going to be able to get the men it needs. The only question is the main one: what are the industries going to do? I was just going to say that inquiry from a number of young chemical engineers who are subject to draft but who, for instance, had brothers who had gone and felt they were the only mainstay for the old folks at home, inquiry at Washington brought out the advice to get into munitions plants. Apparently these are going to be protected. Some of them have gone into chemical plants where they are making munitions as a side issue. They have some information that those industries are going to be protected.

The SECRETARY: I would like to ask if you think it is advisable for this Institute to adopt any resolution on this question; that is,

whether it would have any effect if the American Institute of Chemical Engineers adopted a resolution with reference to what we thought the policy should be in protecting chemical industries, or sent a letter to the President?

Dr. JAMES R. WITHROW: I think that is a happy thought. This is a delicate subject, nevertheless I am convinced from my talks with Government officers that they will overlook an obvious thing and if it has been suggested to them it might be a real help. I understand there is a board actively engaged in what the exemptions shall be and they are having a serious time over it and I think if we could come in with something helpful to them, something helpful to the country, we should go into it, and I would like, therefore, to second the resolution.

Dr. JAMES S. PALMER: I move that such a resolution, carefully worded, by a committee to report Friday, be forwarded to the proper authority. I am not sure whether the proper authority is President Wilson or Dr. Bogert or Secretary Parsons of the Chemical Society. I want to say I am very much interested in this subject and we have had resolutions and we should hold ourselves in readiness to help the Government in our special line in chemical engineering and chemical industry. I know that one of my friends, I may say confidentially, through the direction of Secretary Parsons of the Chemical Society, is going with some military commission, captain or major, in the capacity of chemical engineer advisor in some department, I cannot say which. This idea of needing the chemical engineer in his business is something that is correct and we must be very patient with our Government to work the idea out. We had an address before a chemical society by Colonel Jadron of the Engineering Corps, and when the idea was brought before him he heartily approved of it. It evidently is the right idea and we should draft a resolution and it should be forwarded properly.

Dr. WILLIAM P. MASON: It seems to me such a resolution would do a lot to protect the young enthusiastic students from themselves. To quote an instance, we have chemical engineers with us—and I might add the number is growing rapidly—a young man wanted to get into the army at some grade lower than field marshal and he said if he could not get in in any other way he was going to be cook. It seems to me, although I do not wish to throw any mud on the cook, it is a poor plan for a chemical engineer to start in just that

way. It leaves chemical engineering to take care of itself as best it can. We have had a number of students leave us; we are expecting to lose a lot more, but we are not changing our plan of instruction at all and we have made no changes in the number of the faculty, although we doubtless will have a good many in the faculty that will not have any too much to do; we will still keep the faculty as full as ever. I think that resolution will do a lot of good and let me add just this, a line of argument that I have used as against these wood-be cooks: we have students who come to us, graduates of Annapolis, all those who are going to the bureau of yards and docks come to us, and what does the Government do about them? Does it pluck them out and set them to work directly? Not at all. They are right with us and are going to stay with us until they graduate. And that is the argument I have used against the mistake some of these youngsters would so willingly make. What does the United States do with men they own body and soul? They keep them right there and get the product finished before they take them.

Dr. JAMES R. WITHROW: I wish to second those remarks of Professor Mason. We have exactly the same situation. The United States is sending to our institution ten to twenty new enlisted men every day to study branches of engineering and aviation. The government sent the professors up to Toronto, Canada, to learn at a Royal aviation school there, some of the fundamental things to instill into those men. I want to state here, parenthetically, that I think Dr. Parsons, or any other chemist would not be a proper one to send these resolutions to; in other words, let us stand on our own feet. I am not disparaging anybody else. I think it would be better and have a better effect on the army if we did stand independently. Those men in the American Chemical Society have doubtless put up their point of view to the government and this will independently back up what they have done.

Dr. JAMES S. PALMER: I think we should feel our way very carefully.

Mr. HARRY O. CHUTE: Would it not be better to have the committee that draws up the resolution be the Educational Committee, and as Dr. Baekeland is on the Council of Defense, and I believe Dr. Nichols is also, both of whom are members of our Society, would they not be the proper channel to bring it officially before the Government?

Mr. GEORGE A. PROCHAZKA: I represent an important chemical

industry and I look forward to the future with considerable misgivings as to how to keep the organization alive if our chemical engineers are going to be drafted to the army, and so the resolution, as proposed, has really frightened me.

Mr. ARTHUR B. CONNOR: I would like to state that the day prior to the draft our concern received a telegram from the Government stating that we should instruct our men that they could claim exemption and would be glad to have them claim exemption if they were key men in the organization. That has nothing to do with chemical engineering education, but it is in answer to that point of Dr. Prochazka. There would seem to be a tendency on the part of the Government to protect the industrial organizations in holding their men. Any key men could claim exemption and they would be glad to have them do so.

The CHAIRMAN: The motion, as I understand it, is that a committee be appointed to draw up a suitable resolution, as suggested by all this discussion, to be presented at a later time during this session, that is to say, on Friday; and there is no number given in that committee. I suppose that can be determined by the Chair if it so desires. Are you ready for the question as to the appointment of this committee?

Dr. JAMES S. PALMER: I would like to ask for information. Would it be better to modify the motion so that it should be made up of the Committee on Chemical Engineering Education?

The CHAIRMAN: They are not here, all of them; and as to whether a resolution ought to be adopted here, whatever else should be done about referring to another committee for carrying out the performance of the resolution, that is up to you gentlemen to decide. I simply point that fact out.

Mr. GEORGE A. PROCHAZKA: It looks to me as though there is no time to be lost.

Mr. ARTHUR LOWENSTEIN: I would like to ask that this organization instruct that committee—it can best be done by amendment—to coöperate with existing agencies of the American Chemical Society who have done a good deal of work on this subject. Dr. Stevens has reported at Kansas City and later to the Chicago session in a preliminary way; Dr. W. H. Nichols, I think, was the author of the statement that the Government wanted to protect key men in the plants from being selected, and he has worked in conjunction with the National Council of Defense. Dr. Parsons

has done considerable work. In other words, this whole matter has been before the President of National Council of Defense and the National Research Council. It is not my thought to restrict the chemical engineers in any way, but I think this committee ought to get thoroughly posted on what has already been done.

Dr. JAMES R. WITHROW: I think it will be stronger if it comes from an independent organization without any apparent coöperation of any kind. I think undoubtedly the committee should be advised on what has been done by other organizations.

The CHAIRMAN: You have heard the motion on the appointment of the committee. Those in favor of the motion say aye; contrary minded?

The motion was unanimously agreed to.

The CHAIRMAN: I will appoint Dr. Withrow, Dr. Palmer, Dr. Mason, Mr. Wesson and Mr. Kingsbury on that committee. If they can report something by Friday we can dispose of it.

The Committee reported on Friday as follows:

Prof. JAMES R. WITHROW: This committee has met repeatedly since it was appointed, and we have together and separately read the notes that we have collected together to a considerable number of the members of the Institute yesterday and the day before. Each time we read this to different members we had additional good suggestions, so that the report incorporates all of those suggestions, and is as yet, we feel, too voluminous, and so I am going to ask, after reading it carefully, for suggestions here from the floor, and in addition that we have the privilege of turning it over to the Chairman and Secretary, giving them power to amend it or condense it where possible before transmission. I will read it slowly so that it will be understood. It was our purpose to have this sent at least to the President of the United States as Commander in Chief of the Army and Navy, to the National Council of Defense, and to the Provost Marshal.

Reads resolution.

Dr. CHARLES S. PALMER: Mr. Chairman, I move you that after discussion and suggestion which may come up here, this report be in substance recommended as the report of the American Institute of Chemical Engineers, and be entrusted to the hands of a committee consisting of Dr. Withrow, the Chairman and the Secretary, with power to incorporate or to modify by any suggestions which may be put in this morning, any such suggestions to be put in in writing.

The motion was duly seconded.

The CHAIRMAN: I would suggest, if you do not mind, that that motion be now discussed, but we will make the discussion broad enough so as to cover the entire report of the committee, and then we can adopt the motion after the discussion. It will really be better for us to adopt this motion, if it is agreeable to you, after we have had the discussion. So that now the discussion of the report is before you.

Mr. MAXIMILIAN TOCH: Mr. Chairman, this report is excellent, but with all frankness I believe it is incomplete. What I am about to say is naturally largely based or to some extent based on hearsay, but I am familiar enough with the subject to know that it took England fifteen months to realize that the doctor of philosophy had to be taken out of the trenches and put to work where he could serve his country best. It took France almost as long to realize that its scientific and engineering skill should be taken out of the trenches and put back in the factories; and unfortunately for both England and France, both of these conditions occurred after many very important and skillful men were killed. Those of us who belong to the German chemical societies will probably remember that during the first three months of the war, when we still received the publications of the chemical organizations to which we belong, on the last page were double column lists of doctor so-and-so who, in the language of the front, has earned the hero's death. But after three months Germany woke up to the fact that this was not a good thing; that it took six years to make a man of that kind and it took but a second to kill him. It took only three months or a little more to make an officer of a man of his skill and ability—a military officer. Therefore what was the use of killing off these men who were vitally needed in the munition works, in the chemical works, and in the mines and wherever commerce was needed, commerce relating particularly to the conduct of the war. I am an employer, as many of you know, of quite a number of chemists. When those boys came to me who are under thirty and signed their statements I asked those whom I felt should not be drafted to put down, "I believe I will be exempt on account of commercial necessity." It simply means that if those men were to be taken away from me it was going to cripple an organization which is of some value to the Government directly or indirectly, and a statement of that kind should be embodied in the resolution so that those in Washington

who read this may fully understand that to take away the scientific men, whether they be chemists or engineers or skilled machinists or what not, who are of vital importance to the conduct of this war, would be wrong, and my opinion is that no man who has had a scientific training and who is of value to the commerce of this country ought to be taken until the last man who is unskilled is available. (Applause.)

Prof. JAMES R. WITHROW: I quite agree with that, and I would like to ask Dr. Toch if he would not write out a brief paragraph to incorporate that idea.

Dr. MAXIMILIAN TOCH: I shall be very glad to do that.

Mr. HARRY O. CHUTE: One paragraph there struck me as perhaps unfortunate or at least might be open to misunderstanding by the military authorities who do not appreciate the chemical point of view, namely, the expression that the chemists should be exempt from military service. There are many places where the chemist could be of service in a military way, even in the trenches, and if that expression could be so modified as to plainly show that it only is meant that military service which could be performed by unskilled people that the chemist should be exempted from, it might be a little bit better when being presented to the military authorities. The chemist who stays behind and manufactures explosive is just as liable to sacrifice his life perhaps as those who go to the trenches. In the broader sense he is in military service, but he is not on the fighting line perhaps as in the ordinary sense, but he is on the fighting line because he is serving his country and aiding the military efficiency, so that it seems to me that the committee ought to further modify that sentence.

Dr. MAXIMILIAN TOCH: I would like a little explanation on that if you will pardon me for a moment. I do not quite see how you are going to put a skilled man in the trenches and keep him out at the same time.

Mr. HARRY O. CHUTE: You cannot keep him out but if he is going to do his chemical work there in the trenches which may be on elimination of poison gases or something like that it is very important.

Dr. MAXIMILIAN TOCH: That is all right.

Mr. HARRY O. CHUTE: That is why I objected to that expression not doing military service, because some chemists are necessary in military service, but they should be there only as chemists.

Dr. CHARLES S. PALMER: I think that is a most excellent point.

Chemists are needed in the military service as chemical engineers to accompany the army to the front in certain cases, but as you say, they should go only as chemists.

Mr. HARRY O. CHUTE: The army behind the allies has failed oftener than the army in the trenches. In other words, they failed for lack of skilled men, men skilled in the manufacture of munitions, more than they have for lack of military skill in the trenches.

The CHAIRMAN: If there is no further discussion I will put the motion, which was in substance that we approve in general of the report of the committee, and that in order to put it in final form a committee composed of Dr. Withrow, your Chairman and the Secretary be appointed to revise and incorporate such suggestions as are made here and transmit the communication.

Prof. JAMES R. WITHROW: I would just like to state that I agree quite with Mr. Chute's remarks, because while it is true that the military is using chemists, and has taken some of them for the military service, yet the military will be required also, in my opinion, as was brought out in the discussion a few days ago here, to take along civilian chemists who are left here for exclusively military services.

Mr. HARRY O. CHUTE: We understand what you mean by chemists but the people to whom the report goes do not understand what we mean.

Mr. L. D. VORCE: There is another point I would just like to emphasize in that connection, and that is the point that is raised in the resolution as to giving some designation to these chaps who are exempted. I had occasion recently to go through a plant in which I was interested and talked with the young men, and we all know that every last one of them has a holy horror of being thought a slacker. A lot of those young men, some of the most important in the organization, were very strongly inclined to go and enlist. And I had to put it up to them very strongly that they were needed more where they were than to go out into the trenches, that anybody could become a target, but after they had spent their time in learning their art and in practicing it they were of greater value to their country where they were. It is extremely important that a badge or designation of some kind be given to these men so that it will show on its face that they are doing their part for their country.

Mr. HARRY O. CHUTE: In the Fall of 1915 I was over in Canada and came in contact with a number of chemists who had been employed in the Woolwich Arsenal and other places in England. I

remember one of them telling about the excited females in England who passed around white feathers to any young man whom they saw who was not in uniform, and he spoke about showing his badge to them, so that at that time England gave some kind of a badge or mark by which they could show that they were engaged in work pertaining to military efficiency, and undoubtedly that is a very valuable suggestion, because the young man wants some evidence that he is serving his country even if he does not wear the khaki; and perhaps in that connection a broad statement might be made to include all the chemists that we want exempted by showing those who are engaged in industries contributing to the military efficiency of the United States. I think it would be impressive to the Government officials.

The CHAIRMAN: I think all of this discussion can be very readily run off and a copy sent to Dr. Withrow as soon as we return to New York and then he can have that discussion as the basis for material for incorporation in his report.

Are you ready for the question now, gentlemen? Those in favor of the motion say aye.

The motion was unanimously carried.

The SECRETARY: Mr. Chairman, I would like to suggest that it might be advisable to send a short telegram to Secretary Baker or President Wilson, stating in a few words that we have adopted a resolution requesting or urging the exemption of chemical engineers and chemists from military service, unless their chemical ability is needed. My idea is that this full resolution might take several days or possibly a week, and then it might be published, etc., and as a matter of courtesy I thought it might be worth while sending a brief telegram telling what we have done, and that we follow later with the full resolution.

Mr. HUGH K. MOORE: I think I can tell you what the result of the telegram will be in advance. As a member of the Naval Consulting Board I had occasion to write Secretary Baker offering the services of our laboratory. In fact, we even offered to build separate laboratories and work on anything secret they wanted, where we could have them away from places of explosions and everything else, and I found that my boys, having a tendency to enlist, disorganized the machinery which we had so carefully built up, so that I wrote Secretary Baker telling him of the situation, and I got a reply saying they had chemists enough and did not need any more.

Dr. CHARLES S. PALMER: Mr. Chairman, I think the suggestion of Secretary Olsen is eminently in point and I move that such a telegram be sent at the discretion of Prof. Withrow and Dr. Olsen, if it is agreeable to the Institute.

The motion was duly seconded.

The CHAIRMAN: I am very much in favor of the telegram, if you will pardon me saying a word, but I am just a little bit in doubt as to what the effect of a telegram of that kind would have that simply refers to the exemption without some more ample statement as to the services chemists can render. I am thinking more of the effect upon the public; not upon the President, because a telegram of that kind might be made public, and it would simply appear as though we were endeavoring to get chemists out of service. As a matter of fact what we are endeavoring to do is to get chemists in service on the line in which they would be most efficient to help the country. But if you want to adopt the resolution I am quite sure with what I have indicated that the wording should be so that there would not be any misconstruction of the meaning.

Dr. CHARLES S. PALMER: I would like to add your own name to that of the committee and have it left to the discretion of the committee, and understand that the Institute will stand by you whatever you do.

The CHAIRMAN: Gentlemen, you have heard this motion, that a telegram be sent to the Secretary of War, expressing in as few words as possible the thought which is contained in the general letter which will go later, and that the same committee be empowered to draw up such a telegram. Those in favor of the motion say aye.

The motion was unanimously agreed to.

The following telegram was sent to the Secretary of War:

Buffalo, N. Y., June 22, 1917.

Secretary of War,
Washington, D. C.

DEAR SIR: The American Institute of Chemical Engineers in Convention, Buffalo, N. Y., desires to emphasize the importance to the military effectiveness of the United States of Chemical Engineers and Chemists being permitted to remain in our industries as only by so doing can our military supply production be maintained and increased as required. Every member present expressed a sincere

desire to be of service to his country in the most effective manner. Full resolutions will follow.

(Signed) J. C. OLSEN,
Secretary.

The following letter was sent to the President and also to the Secretary of War:

July 11, 1917.

To the Honorable President of the United States,
Commander-in-Chief of the Army and Navy.

DEAR SIR: We, the members of the American Institute of Chemical Engineers, in Convention assembled at Buffalo, N. Y., June 22, 1917, desire to offer you our services in any capacity in which you may see fit to call upon us in the present national emergency. We know that it is your desire to reduce to a minimum any injury to the industries of our country by the indiscriminate drafting into ordinary military service of such skilled help as chemists and chemical engineers. Some manufacturers, having perhaps productive units small in capacity, have not as yet been disposed to initiate claims for protection against the virtual destruction of their business either through voluntary or draft enlistment of their chemical help.

The chemical industries of the country are both directly and indirectly indispensable as a source of military supplies. A large part of modern efficiency in many industries is dependent upon adequate chemical engineering and analytical control. Skilled chemists are the result of years of training and experience in connection with chemical phenomena and the efficiency of such chemists is similar to the efficiency of skilled naval officers, who have also had years of training and experience to develop them for their responsibilities.

We urge upon you, therefore, to avoid the errors which in the earlier stages of the war were committed by all combatant nations in weakening their industrial operations by taking technical men from the industries without due consideration as to the relative needs of these industries. We feel it our duty to ask of you that all manufacturers and producers using chemical means of manufacture or control be required to list with designated officials for exemption consideration all employees as follows:

A. All employees engaged in the production and its direct control.

B. All other members of the organization. These latter to be grouped.

1. Key men in the organization.
2. Men highly desirable but not vital to the industry.
3. All other employees of organization not engaged in production.

With the data thus at hand the Government will be able to protect itself against any stalling of industry that might jeopardize a speedy prosecution of a successful war. We do not wish to be understood as wishing in any way for exemption in such industries as are connected with luxuries merely or are in no way connected with essential military effectiveness, though serious attention must be given to the possibility of wrecking national effectiveness by the withdrawal of such key men as chemists from most of our industries.

We urge that a suitable badge or other system be devised for the social protection of men exempted for their industrial service.

We also request that the Government urge or assign to a continuation of their college studies a sufficient number of engineering and particularly chemical students, so that the Government and industrial service will not be denied this necessary yearly influx of young chemists and engineers.

We are gratified to find that the number of chemists and chemical engineers who have volunteered for admission to the Ordnance Corps and other departments where their chemical experience can be of direct benefit in military service has been in excess of the requirements. We know that this is the spirit which animates all of the chemists and chemical engineers of the country. We know that they want to be where they can be of greatest service. They believe that their greatest power of service is:

First, in the industries on which the success of the war directly depends.

Second, in such departments of the military service where their knowledge of noxious gases will enable them to be of help in the prevention of loss of life and in the repair and maintenance of equipment. When they are not needed in either of the above classified departments of service, they are willing to do any kind of work and lay down their lives if need be.

Very truly yours,
J. C. OLSEN.
Secretary.

Acknowledgment was received from the White House and also from the Council of National Defense, to which both the letter to the President and to the Secretary of War was referred.

Washington, D. C., July 18, 1917.

Mr. John C. Olsen, Secretary,
American Institute of Chemical Engineers,
New York, N. Y.

DEAR SIR: Your letter of July 11, addressed to the President, has been referred to this department for reply. I wish to thank you on behalf of the Government for your patriotic offer, a record of which has been placed on file.

You will understand that the magnitude of the task makes it impossible at present to say to what extent the Government can use your services, but I assure you that we shall be glad to avail ourselves of your offer should the occasion therefor arise.

Very truly yours,

W. S. GIFFORD,
Director.

REPORT OF THE COMMITTEE ON CHEMICAL ENGINEERING EDUCATION

Read at the St. Louis Meeting, Dec. 5, 1917

1. No further word has been received from the Carnegie Foundation or concerning its report since the last meeting of the Institute.

2. It is understood that this report is completed and will shortly be in the hands of the Advisory Committee.

3. The Society for the Promotion of Engineering Education, which, as mentioned in the last report, was contemplating holding a meeting at Northwestern University for the discussion of the engineering report of the Carnegie Foundation by professors and officers of the various engineering schools and colleges of the country, abandoned this project because of the war situation to meet in Washington for the discussion with the Secretary of War and others, ways and means for the best assisting of the country and the students who would enter the army under these war conditions.

4. The various educational institutions have cooperated with the Society for the Promotion of Engineering Education in petitioning

Washington to protect them against the loss of young instructors so as to obviate the curtailment of training of young chemists needed so much in war industries and particularly in the development and rehabilitation of industries which must come after the war. This petition is bearing fruit in orders about to be issued by the Chief of Engineers, U. S. Army for the re-assignment of engineering students back to their studies. This will include chemical engineering students. Other projects for protecting the government and industries in this matter of conserving chemical help are on foot.

5. The resolutions passed by the Buffalo Meeting of the Institute were of value in this connection and one of its petitions has already been favorably received. Unfortunately, most of the resolutions seem lost, particularly the reference to protection of industries from loss of chemical help, by reference of the resolution to Director Gifford of the Council of National Defense who gives no evidence in his reply of understanding its requests, but merely thanks the Institute for its offer of its services.

JAMES R. WITHROW, Chairman.

INTENSIVE PREPARATORY CHEMISTRY

By CHARLES S. PALMER

Read at the Buffalo Meeting, June 20, 1917

For years we have all been dreaming of sound training in preparatory natural science. We are familiar with the conventional one year each of physics, chemistry, and biology—with always, of course, good mathematics—if we could only get it—but that is another story. We are talking of chemistry.

We tried to be broad in our judgment, for we did not know which is the fundamental science—nor even if there were one fundamental science. It is one of the many curious awakenings of this awful world war, that we chemists have been rudely jolted into the realization of the obvious fact that it is our own chemistry which is the fundamental science. We knew that we are born with all sorts of possibilities—linguistic, mathematical, idealistic, materialistic—and that it is one of the main facts of practical psychology that contact with the material things of the world wakes us all up to the use of our bodies through our minds, and *vice versa*. This is so obvious that it is both trite and humiliating to be reminded of it; but why have we taken so many valuable years to wake up to the facts? At any rate, we are here, and we just begin to realize that the careful study of things is the start and the foundation of conquering the materials and forces of Mother Nature. We are, most of us, samples of the routine training of our colleges and universities. We are keenly interested in the training of our younger brothers. We feel our deficiencies. Let us get busy and try to make the best possibilities for the better training of the little brothers who are coming to such demands as we never dreamed of.

And let us look for a moment at the mass of subjects which are now fairly included in this same study of chemistry—this study of things. We have not only the good old inorganic and organic; the fundamental analysis, qualitative and quantitative; but we

find the field of what is conveniently called "physical chemistry" insisting in a safe and sane way that we know only half our things, unless we know the energy relations of these same things. Just count them over—the various sides of this same physical chemistry: spectrum analysis, crystallography, pyrometry, electro-chemistry, catalysis, mass action, phase rule, dissociation, argonoids and the periodic sequence, radiography, colloids, x-ray-ology, etc., etc.!

What are we going to do about it? Why, do the right thing, of course—the obvious duty for the obvious need. True, the average mind cannot be well trained, and equally well trained in each and all of these lines—and these many lines are infinitely multiplied and diversified when we consider their applications to the many old and new specialties of industrial demands. And, in general, while we cannot expect the Ph.D. candidate to know it all, yet he must be on speaking terms at least with all of these subjects, to attack the many sides of his research work, and to be able to compete with other efficient men in the modern struggle of theory and practice.

Moreover, there is another phase of the question which we should note. The field of leadership in science and civilization is bound to swing to the western world. Not that we are there yet, not that we are yet capable of shouldering the tremendous burden; but the tendency is here, and we may as well recognize that Europe is depleted, in strength and resources; this country is rich in strength and ambition. It will take years to assume the honor; but the responsibility and opportunity are here. What are we going to do with them? Shall we not begin to trim our sails for the tempest of opportunity and competition which meets us, right now?

There is also another aspect of this question. We are in name, practical men, industrial men, but we are interested in the proper training of chemical engineers. For chemical engineering is only good old-fashioned engineering, guided and directed by some chemical idea, some chemist; and this chemist must be properly prepared to meet the crisis—a crisis which is full of interest both for him as an individual and also for the public.

And so we hear the clear call: "More Chemistry." For the student who goes on to college and university, more chemistry; but none the less, for the student who cannot go on to college,

for the student who cannot go beyond the high school, we hear a thousand more times insistently, the clear call, "More Chemistry."

There are many other reasons why we should heed this call. There is the need of some good business training, with all the rest; and we find the college curriculum filled and overflowing. And so we look to see whether we cannot save time for all concerned by looking at the preparatory and high school, where we see how much time may be saved, as we ask that these claims be considered.

1. A year of good general elementary inorganic chemistry; with lecture, laboratory, and recitation; and with the best intermixture of both theory and practice from the start; and with all of the "new" and the "research" ideas that are suitable, from the start.

2. A year of good organic chemistry; lecture, laboratory, and recitation.

3. A year of good analysis, qualitative mostly, but enough of quantitative to give the idea, and to correct the usually sloppy methods of the beginner.

Now this may sound absurd and romantic; but I know from personal experience that it can be done; for it was the lot of the writer many years ago to teach preparatory work in a western university; and it is clear that good students can take easily what we call the elements as just outlined. And think what this would mean for the college work, where the student could begin to handle some of the mass of material, of all of which he must know something.

The college is already overloaded; but with the proposal worked out, it would be freer to do its part in getting the student ready for the real graduate work which is to follow.

And here we come to another point which we, as engineers, must consider, namely: If we are to have a good supply of chemical engineers for the future, we must see to it that not every young student is drafted prematurely to the front of industrial work. We must insist that a good part of the student body shall stay with the university till he is equipped with the best that theory can give him. Not that all chemical engineers need this advanced training, though probably many of us would profit thereby; but it is true that a large proportion of our best men should have the best training to meet the hard problems which lie all along the line of progress. Of course, I do not assume at this time to dis-

cuss what shall be the methods of training in this advanced graduate work; doubtless there will be many changes and modifications, but the main point is that there shall always be an adequate supply of the best trained men to fill the ranks of the practical men; and, in the long run, now and then it may be well for some of the successful practical men to go back and help the force of teachers, to keep the spirit of the times broad and properly balanced in scope and aim.

There are many things which should be said in explanation and enforcement of this scheme of good preparatory chemical training—to help the college—to help the graduate work—to help the engineer—to help the world. But I will leave the proposal here, with some few remarks as to special features and reasons.

1. The plan of three years of preparatory training, in chemistry, inorganic, organic, analytical—meets special chemical educational needs and natural needs.

2. The plan is good for those going on to college, and also for those not going on to college.

3. The plan meets college objections against giving credit for one-year preparatory work.

4. The plan is good for all college students, in that it gives thorough special and intensive work in high and preparatory schools.

5. The plan meets objections of favoring one science: in that chemistry is not too general, like biology; nor too mathematical, like physics.

6. The plan matches co-ordination with the other fundamental studies, like English, history, languages, mathematics, and general science, in the already overcrowded high school and preparatory courses, and thus helps to simplify the work.

7. The plan actually helps co-ordination and specialization, in that students who are well trained in a few things, can the more easily master other subjects; thus the well-trained chemical student can concentrate his mind the more easily on other subjects.

8. The plan has been tried by some in special cases, and is no idle dream.

9. The plan is peculiarly suited to the memory needs in mastering the encyclopedic details of even the elements of chemistry. Memory alone should never be made the basis of scholarship in any subject. But it is a fact that none of the other fundamental sciences demands the accurate memorizing of so many fundamental

facts as does elementary chemistry. Hence, the student must be caught young, when the memory easily gathers in and retains what is later acquired with more difficulty.

In closing, I would suggest that we should study this proposal, and convince ourselves that some such plan is desirable, is feasible, is necessary. Then it will be proper for us, as one of the leading chemical societies of the Nation, to approach the schools, as the natural avenues will open up. I have proposed this in some of the local western Pennsylvania work; and also in the National Educational Association. But it will take some years to even get such a scheme well started. I once discussed this with President Eliot of Harvard; he smilingly gave his entire approval to it. "But," said he, "while the scheme is all right, remember that you will have to wait for another generation to bring it about." That was over twenty years ago. Perhaps the right time has come. It certainly looks as though the psychological moment has arrived, both in opportunity and in necessity.

DISCUSSION

The SECRETARY: Dr. Palmer has proposed quite a radical change here in education, namely, to introduce the teaching of three years of chemistry in the high school. In my seventeen years of teaching in technical schools and colleges I have been up against the high school graduate who comes to take chemistry and I have had to study this very proposition and I would like to say a few words on the subject. In the first place the teaching of chemistry in the high schools has two very distinct objects, because we have in the high schools two classes of students at least; there may be more. We have, on the one hand, a large number of boys and girls who go to high school, but never go to college or to a technical school, and on the other hand we have the young men particularly and also the young ladies who go to high school in preparation for college. Now, you must consider these two classes separately. I do not think the high school teachers have generally done so. I think the high school teachers have looked more toward the colleges and have prepared for college instead of preparing for life.

I can readily see that Dr. Palmer's argument is excellent for the young man and young woman who never go to college. I think our chemical industries, as well as our chemical profession,

will be supported and strengthened, and will get more popular support for the chemical industries if we have a larger body of the general public who know more chemistry, and understand it better. If the average business man, if the banker, if the financial men knew more chemistry, they could more intelligently support chemical industries. In the City of New York chemistry is not required for graduation from the city high schools; physics is required, but chemistry is optional; and I can see how there could be quite a propaganda along the lines suggested by Dr. Palmer to make chemistry compulsory, and in my opinion it ought to be done in that great metropolis.

Taking the other side of the question, Dr. Palmer brought out the argument that if there were more chemistry taught in the high schools the colleges would get along better, we could teach better. I consider that doubtful. I have had young men who came from the high schools who had chemistry and those who have not had chemistry and the progress of the one class was almost as good as the other, and amongst college men that I have met and discussed this question with, it is considered questionable whether better progress is made in the colleges by students who have had high school chemistry. I think there are two reasons for this. One reason to my mind is that chemistry may be taught so poorly that the student loses all interest in the subject, and that is frequently the case. I met a very intelligent young man about a year ago who has been to one of our great universities and I asked him how he got along. He said he had trouble only with chemistry. He said in that subject he had great difficulty. I responded immediately, much to his delight, "It must be poorly taught." If it had been properly presented, he being a young man of good average intelligence, would have had no difficulty with the subject.

When you take the young men from our high schools and put them into the technical schools or colleges, their taste for chemistry may be spoiled, and they may be less fitted for it than they were before.

I should say to make any campaign of this kind effective we must add to it a strong plea and a strong demand not only for *more* chemistry in the high schools, but for *better* chemistry. If you put the one in without the other, you may do more damage than you do good, and if any members of this Institute will go home and look into the high schools of their immediate community

and ask themselves what kind of chemistry is taught and also how much chemistry is being taught, and exert their influence in both directions, some definite good may be done, but otherwise a great deal of harm will be done. That is my fixed opinion from a long study of this question. Others may differ from me. I am making attempts continually to utilize the high school chemistry to shorten the college course; I am making an attempt now, going into effect next Fall, for that distinct purpose. I am going very carefully just on account of this experience. The high school chemistry from my past experience is not of very great value towards giving a young man a technical education, and I think it is quite as important that we emphasize the quality of this high school teaching as well as the quantity.

Dr. EDWARD BARTOW: Mr. Chairman, I think the last speaker is perfectly correct in the statement concerning the quality and quantity of chemistry taught in the high schools. As a college teacher a number of years ago I received students who had had high school chemistry. Some of them were good and some not. Some students who had had their chemistry in high schools, and had worked with enthusiastic teachers, were as well or better prepared than students prepared in the university, and others under different conditions were not so well prepared. A few years ago I was detailed as a member of a committee to make an examination of the Chicago high schools, my special duty being to study the conditions with reference to the teaching of chemistry and physics. In one of the schools a teacher had four divisions of thirty students each and was kept busy with classes twenty-eight hours a week, being required to teach as many hours of chemistry as teachers of English or other subjects were required to teach. That teacher, a young woman by the way, had to take care of the laboratory and look over the students' note-books. It seemed almost impossible to do justice to 120 students under those conditions. In another high school where the chemistry teacher had a little spare time, he was required to serve as secretary to the principal. In another, the teacher of chemistry was also teacher of bookkeeping, and so forth and so on. Better conditions were found in one of the suburbs, Oak Park, where one teacher had nothing but chemistry, small classes, and a little extra time. He was doing good work and teaching qualitative analysis in addition to the beginning chemistry. At Crane Technical High School, Chicago, I found the best conditions.

The teacher had to handle 120 students, the limit of his laboratory, for more students wanted chemistry than could be accommodated. One hundred and twenty of the best students of the Crane Technical High School were allowed to take chemistry and the teacher was doing excellent work. He was able to draft some of his advanced students to assist him and he gave them some more advanced work. In one year three of six men elected to the Phi Lambda Upsilon (honorary chemical) Society of the University of Illinois were from Crane School.

Mr. ARTHUR: This is one of the subjects I have waited for a good many years to hear discussed. I can well recall my high school chemistry a good many years ago, and think of the slimness and leanness of the course and the manner in which it was taught. Although I have the greatest respect for the man who taught it, I appreciate the conditions under which he found himself. There are several points that come out very, very clearly in regard to this whole matter and while it is an exceedingly difficult matter, I think it is a subject that, just as Dr. Palmer has said, should receive considerable attention.

I had an occasion, as a number of others have had here to-day, of teaching or quizzing or lecturing—whatever you may call it—students who have had chemistry in high schools and students who have not, and if I had my choice as to who I should teach chemistry to, I would prefer to have a student come to me who had never had any chemistry in the high school. I am saying that really honestly and truly, not from any feeling towards the high school, but for the simple reason the teachers in the high school who attempt to teach chemistry are too often unprepared to teach it. The greater number of teachers in the high school are teachers who perhaps have had one year chemistry in a normal school, two years perhaps; occasionally you will find a teacher who has had perhaps quantitative analysis, and you cannot expect water to rise above its own level.

It is highly desirable, of course, that they get as much chemistry in a high school as is possible, but we cannot expect the normal school teacher to teach chemistry unless he has had more training than you get in the average normal school.

Another thing I wish to call attention to, is the matter of lectures in the high schools. Lectures are most abominable things, except in seminary work. In these days of typewriters and sten-

ographers and text-books of all descriptions which are so plentiful, any man who attempts to lecture his students shirks his duty. I have the most complete disgust for a teacher who will waste a student's time, telling him something, handing it down to him by word of mouth when he could put the written matter in his hand and let him study it, and then, if he wants to, make a test of his knowledge. It will then be instruction and not a means of enabling a teacher or a professor to make a little display of himself before the students. I have suffered that myself; I have had men lecture to me who had no more interest in what they were saying than the students who were listening to him. How can you expect the teachers in universities to teach anything of that kind to the students when we have a much more difficult condition to contend with. If a lecture method is employed in the high school it may work, but it is a mighty poor method of teaching.

I am not saying this without the best support in the country. Nicholas Butler, the President of Columbia University, only a few days ago condemned it most strongly, the matter of lecturing to the students.

Another respect in which I think we are very much lacking in the matter of teaching chemistry, not only in the high school, but in the university, is that we get into the habit of mind of looking backward. History of chemistry is all right, but we want to instill into the mind of the pupil the attitude of mind of looking forward and keeping his mind open. I dare say half of the men, or the greater number of men, have their minds closed to new suggestions or new things. We find it constantly in the shops. It is the hardest and most difficult thing to drive any new thing into the heads of employees; and it is one of the things we want to instill into the mind of the student, to keep his mind open, to look forward, not to hark backward all the time. That should be one of the most important elements in any education to prepare the man's mind first and then teach him, to keep his mind open for advancement.

This matter of teaching chemistry in a high school interests me very greatly. I have thought about it a great deal and I have been tempted a number of times to take up the matter and discuss it. This is the first time I have ever heard anyone who was brave enough to speak on the subject, who even dared to express himself. I congratulate Dr. Palmer on his efforts.

THE POSSIBILITIES OF DEVELOPING AN AMERICAN POTASH INDUSTRY

By RICHARD K. MEADE

Read at the Buffalo Meeting, June 22, 1917

I had started this paper some month or so ago by quoting Prof. Ostwald's well-known remarks concerning Germany's ability through her control of the only known large deposit of potash salts to say which of us "unkultured" nations could eat and which would do without our meals. Since making this beginning, however, I have read about a dozen papers on potash and several prospectuses of proposed potash producers all of which have taken great pains to quote the professor and generally to show him the error of his conclusions, hence I have recast my introduction and will only refer to Ostwald's remarks by saying that I know of some millions of dollars which would be invested in establishing a potash industry in this country if we could be sure Germany would be inclined to exact stiff terms from the United States or dictate that she should go hungry. The thing that keeps this money out of such an investment is the fear, not that we won't have potash from Stassfurt as heretofore, but that we will have too much and that the German producers will be so glad to get Yankee dollars to pay their war debts that they will offer us potash on the same old \$40 basis.

If the American investor can be assured against the dumping of German potash salts into this country after the war at prices too low for us to reach, I know that we can develop a potash industry in this country and in Canada which can more than take care of our needs for both agricultural and chemical purposes and which can sell potash at a price which will work no hardship on any users, and it is my purpose in this paper to outline the sources from which to me it seems most promising to produce American potash.

The present employed methods of obtaining potash in this country may be grouped under four general heads.

1. By the evaporation of the brines from various lakes and marshes.

2. From kelp and the ashes of various plants.
3. As a by-product of various industries, chief of which are the cement, iron and beet-sugar and molasses industries.
4. By the decomposition of alunite and silicate rocks, chief of which latter are glauconite and feldspar. Numerous other silicates are also available among which are leucite and sericite.

BRINES AND LAKES

It is natural that the first attempts to obtain potash in this country were connected with the evaporation of brines from various lakes in the western part of the country. Geological Survey reports even before the war had called attention to the large amount of potash contained in the waters of some of these lakes, notably Searles Lake, in Southeastern California, which has been made the subject of extensive investigations on the part of the U. S. Geological Survey. The American Trona Corp. was organized in 1913 to exploit this lake and even before the war had planned to spend something like \$3,000,000 to build a railroad and to install the necessary machinery to recover borax and potash from this water. At that time, more particular stress was laid on the borax than on the potash.

Searles Lake is located in the extreme northwestern part of San Bernardino County in southeastern California about 30 miles from the Southern Pacific Ry. at Searles. It consists of a dry bed of crystalline salts, hard enough to support a wagon and team. It occupies an area of from 11 to 12 square miles and has a depth of approximately 70 feet. The deposit contains in the interstices between the crystals a saturated brine estimated at 25% of the volume of the bed, and carrying approximately 2.1% potash (equivalent to 4% potassium chloride) and about 1.3% borax. An analysis (W. Van Winkle) of the solid matter from the water is given below:

K	6.34%
Na	33.80
Cl	37.04
SO ₄	13.00
CO ₃	7.24
B ₄ O ₇	2.50
Other constituents.....	0.08

By reference to the analysis above it will be seen that the principal products obtained are potassium chloride, borax, soda ash, salt and sodium sulphate. Of these products the salt will be largely in excess of all others.

I understand the American Trona Corp. has expended \$2,500,000 to date in developing this property of which \$600,000 has been spent for the construction of a 30-mile railroad connecting the lake with Searles on the Southern Pacific Railroad. The company has built two plants, one at Trona where the brine is evaporated and the other at San Pedro, Cal., where the solid salts obtained from the evaporation are brought and separated.

The American Trona Corp. has shipped quite a large quantity of potash in the past year. I understand that from the chemical standpoint an objection is raised to their product owing to the sulphates and borax which it contains and I am also informed that the fertilizer people have objected to the product on account of the borax.

A second plant at Searles Lake has recently been completed and is under the joint control of the Pacific Coast Borax Co. and the Solvay Process Co. This plant proposes to recover borax and soda ash as well as potash salts from the brine.

There are numerous small lakes in the region of the Sand Hills of Nebraska, the waters of which are more or less alkaline and also contain potash. This potash is believed to have resulted from the leaching of the ashes from numerous forest fires which have occurred in that section. The larger and deeper of these lakes are only slightly alkaline and the only ones which are at all rich in alkali are the small lakes.

The Potash Products Company, of Omaha, Neb., has been for some time a producer of potash which they obtain by evaporating the waters from Jesse Lake in this section. This lake covers 240 acres and is located 300 miles west of Omaha and 3 miles north of Hoffland. The lake is underlaid with a dark greenish colored mud, beneath which is a 20-foot thick sandbed strongly impregnated with brine of greater concentration than the surface waters. This brine contains about 13% solid matter of which latter from 25 to 30% is soluble K_2O . The Potash Products Co. has a capacity of about 75 tons of dry salts daily and their product will probably average 28% K_2O so their total output is approximately 21 tons of K_2O per day. No attempt is made to separate potash

from the other salts and the material is shipped as evaporated. The potash is in the form of carbonate and the product also contains a large quantity of the carbonate of soda.

Other of these small lakes are being developed by the Hord Alkali Products Company of Lakeside, Neb.

The officials of this company inform me that it owns about 50,000 acres of land in which these alkali lakes are located but that their development work has only been carried about a year in advance of their requirements. This company began construction of an evaporation plant about a year ago and started operation Jan. 1st, 1917. Their plant has a capacity of about 40-50 tons of product per day working on brine of about 1.075 sp. gr. This brine is pumped from wells located in lakes the surface water of which is comparatively fresh (containing less than 1% of solids). The plant itself is located on the main line of the C. B. & Q. R.R. at Lakeside. It is equipped with triple effect evaporators for preliminary concentration and single effect for the salting out. The concentrated salts are fused to a clinker in a small rotary kiln, ground in a Stedman disintegrator and packed in sacks of approximately 200 lbs. each. The product has the following general composition:

Na ₂ O	33.30
K ₂ O	21.82
SO ₃	16.98
Cl	4.22
CO ₂	21.87
Loss on Ignition	1.50
Insoluble in Water.....	1.25

100.94

This region is entered by the Chicago & Northwestern R.R. and by the Burlington & Quincy R.R. so that the transportation facilities are excellent. Unfortunately the supply of brine in these lakes is very limited. It is estimated that Jesse Lake, the largest of them, contains approximately 28,000 tons of K₂O.

There are a number of other companies throughout the west who are experimenting on the production of potash from brines. One of these companies is the Inyo Development Company who

have a small experimental plant and are planning to develop the potash resources of Owens Lake.

Owens Lake is situated south of Mt. Whitney and northeast of Death Valley, Cal. The lake is 27 miles long and 23 miles wide and is estimated (H. S. Gale) to contain three million tons of potash. An analysis of the solids from this water is given below:

NaCl	39.51
Na ₂ CO ₃	41.34
NaHCO ₃	4.41
K ₂ CO ₃	2.21
Na ₂ SO ₄	12.06
Other constituents	0.16

Several thousand tons of soda ash have been made at Owens Lake and it is proposed to recover the potash from the spent waters from the soda ash manufacture. These waters were formerly wasted and contained about 4.25% K₂O in the form of carbonate.

Another lake which it is proposed to develop but towards which I believe no material steps have been taken at the present time is Summer Lake in Oregon. This is about 30 miles from Pleasant View, Ore. The water is very similar to that of Owens Lake as will be seen from the analysis below:

NaCl	27.10
Na ₂ CO ₃	43.91
NaHCO ₃	21.41
K ₂ CO ₃	3.63
Na ₂ SO ₄	2.21
Other constituents	0.87

There has been some attempt to develop a potash industry in connection with the Great Salt Lake in Utah. The Utah Chemical Co. is reported to be erecting a plant to make potash from the bitterns obtained as a by-product from the manufacture of solar salts from the waters of the Great Salt Lake. This plant is largely an experimental one.

By referring to the above it will be seen that practically all of the above developments during normal times would be limited

largely by the capacity of the plant to get rid of other products than potash. There is also the objection that none of these waters without treatment with reagents will yield potassium chloride. The Nebraska lake propositions, which would promise most under normal conditions and which are reported at the present time to be making a large amount of money, are quite limited as to brine supply and unquestionably they could furnish only a very small part of the amount of potash which has been shipped to us from Germany.

The developments at Searles, Owens and Summer Lakes will depend almost entirely on the market of the Pacific Coast for soda ash and salt cake and it is hardly probable that under normal conditions the market in that section will be sufficient to dispose of any very considerable quantity of these products. In the case of both Owens Lake and Summer Lake, the quantity of soda to be disposed of is so very much larger than that of potash, that they probably would never amount to anything more than very small potash producers. Against Summer Lake is also the difficulty of transportation and of obtaining labor and the high cost of fuel.

The nearest soda ash plant is at Hutchison, Kans., but it is probable that this latter plant would cut them off from any trade East of the Pacific states so that their market for soda ash would be almost entirely confined by adverse freight rates to the Pacific Coast. Even when it came to shipping potash to the East they would have a very considerable freight rate (above \$6.00) to overcome.

A partial list of producers and companies organized to produce potash from brines is given below:

- American Potash Co., Antioch, Nebr. (Nebraska Lakes).
- American Trona Corp., Trona, Cal. (Searles Lake).
- Hord Alkali Products Co., Lakeside, Nebr. (Nebraska Lakes).
- Inyo Development Co., Keeler, Cal. (Owens Lake).
- Natural Soda Products Co., Keeler, Cal. (Owens Lake).
- Nebraska Potash Works Co., Antioch, Nebr. (Nebraska Lakes).
- Pacific Coast Borax Co.—Solvay Process Co., Borosolvay, Cal. (Searles Lake).
- Palmer Alkali Co., Lakeside, Nebr. (Nebraska Lakes).
- Potash Products Co., Hoffland, Nebr. (Nebraska Lakes).
- Salt Lake Chemical Co., Grants, Utah (Great Salt Lake).

Solvay Process Co., Salduro, Utah (Great Salt Lake).

Utah Chemical Co., Saltair, Utah (Great Salt Lake).

Whitney Chemical Co., San Matio, Cal. (Sea Water).

KELP

The fact that the giant kelps of the Pacific Coast are rich in potash has long been known. As early as 1911, kelp was gathered and dried by the Pacific Mulch Co., Terminal Island, Cal., but no effort was made by this company to do anything more than harvest and partially dry the kelp and chop it into pieces from 6 inches to 8 inches long. In 1913 the United States Geological Survey reported in Mineral Resources that a number of companies had been formed to engage in the kelp industry. At that time, however, no effort was being made to extract potash salts from kelp and the attentions of all producers were devoted entirely to the harvesting, drying and grinding of the kelp.

I believe that the American Potash Company was formed prior to the war and was the first company actively to attempt the production of potash from kelp. This concern had a plant at Long Beach, Cal., where they harvested and dried kelp using an oil heated rotary dryer for the latter purpose. Some dried kelp was sold as such while the rest was burned in a reverberatory furnace and the potassium chloride and sodium chloride leached out of the ash and separated from each other by fractional crystallation. The American Products Co., Pasadena, Cal., later bought the effects of the American Potash Co. and moved to the property of the latter. This new concern was said to be financed by Mr. Geo. Simmons, of the Simmons Hardware Co., St. Louis, and it was reported that their main idea was to carry out a process worked out by Mr. Isaac Naylor in which the kelp was to be so treated that a celluloid composition for knife handles, etc., would be the main product and potash would be obtained as a by-product. Later this company consolidated with several other concerns and became the Lorned Manufacturing Co. The plant as now constituted can make either muriate or charred kelp—most of the output of potash being sold in the latter form. This company has built a second plant at Summerland, Cal.

Swift & Co. of Chicago leased a small plant at San Diego and are harvesting and drying kelp there. They make no effort to extract the potash but are simply drying the kelp and shipping it

to their fertilizer factories in the East where it is used in the manufacture of mixed fertilizers. This plant is interesting as it is said to represent the best method yet tried for drying kelp mechanically. The old plant consisted of two rotary dryers, one 54 inches in diameter by 35 feet long and the other 60 inches in diameter by 40 feet long. The wet material was fed into the cold end of the larger dryer dropping out at the hot end and was conducted from this by a belt conveyor into the hot end of the small dryer, leaving the latter at the cold end. The product which contains 10% water is ground in a swing hammer mill and sacked. The dry product contains the whole body of the kelp including the nitrogen and averages 15% water soluble K_2O . Swift & Co. have now built a large plant containing 10 direct heat dryers 60 inches in diameter by 40 feet long, employing crude oil for fuel. The buildings are of steel and electric drives and modern equipment are employed throughout. The plant is designed to treat 200 tons of wet kelp producing 20 tons per day of dry kelp.

The fertilizing value of the dried kelp is shown by the following analysis:

Moisture	11.12%
Available Phosphoric Acid....	0.65
Insoluble Phosphoric Acid....	0.10
Total Phosphoric Acid.....	— 0.75
Nitrogen	1.24
Ammonia	1.51
Potash	15.11

The Hercules Powder Co. have the only large plant at the present time on the Pacific Coast for actually obtaining potash salts from kelp. Their plant is located at Chula Vista, Cal., and represents a splendid example of chemical engineering ingenuity although it is probably only a war time proposition. The products obtained are potassium sulphate and acetone. The kelp is harvested by machinery and is ground by the harvesters to a thick viscous mass. This latter is pumped into digestion tanks and fermented whereby the slime and other organic matter are converted into acetic acid which is neutralized with calcium carbonate and converted into sodium acetate by sodium sulphate. This latter is a waste product from the acetone plant. The liquid is then evaporated and the

sodium acetate crystallized out. The potash is obtained 80% pure while the sodium acetate is recrystallized and then used in the manufacture of acetone.

This plant is handling about 1500 tons of wet kelp per day, obtaining from this about 18 tons of potash and 24 tons of acetic acid.

The process of clarification, sedimentation, etc., is very similar to that used in sugar manufacture.

The U. S. Department of Agriculture is now investigating with a full size plant at Summerland, Cal., the possibility of the destructive distillation of kelp. The products obtained are gas, tar, ammonia, iodine, charcoal and potash. The gas will be used to partially heat the retort and the potash will be leached from the charcoal.

A list of the more important operators on kelp and their chief product is given below :

California Chemical Co., Summerland, Cal. (Dried Kelp).

Canadian Potash & Algin Co., Sidney, B. C. (Dried Kelp).

Diamond Match Co., Wilmington, Cal. (Muriate).

Hercules Powder Co., San Diego, Cal. (Muriate).

Kelp Products Co., San Diego, Cal. (Kelp Ash).

Lorned Manufacturing Co., Long Beach and Summerland, Cal. (Charred Kelp).

National Kelp Potash Co., Long Beach, Cal. (Charred Kelp).

National Potash & Iodine Co., Bremerton, Wash. (Dried Kelp).

Pacific Products Co., Long Beach, Cal. (Kelp Ash).

San Diego Kelp Ash Co., San Diego, Cal. (Kelp Ash).

Sea Products Co., San Diego, Cal. (Charred Kelp).

Swift & Co., San Diego, Cal. (Dried Kelp).

The possibilities of the production of potash salts on a large scale from kelp as a post-war time proposition do not seem to be particularly bright. The artificial drying of the kelp represents a large undertaking, as for every 20 tons of potash something like 1500 tons of wet kelp containing 1350 tons of water are required. The plant necessary to conduct such a large drying operation is considerable and the type of rotary dryers employed seldom show an efficiency of more than 70 lbs. of water per gallon of oil or about 38,000 gals. oil for 1500 tons of kelp. The cost of this amount of fuel alone would under ordinary conditions eat up most of the price obtained for the product. Under destructive distillation and

the employment of the gas to help heat the retort some saving in fuel could be effected but we doubt if this saving would prove very considerable. We also doubt the value of the charcoal. After the potash had been leached from it, this charcoal would unquestionably contain considerable water and, if anything like the similar residue obtained in the paper industry, no use could be found for any considerable quantity of it.

The manufacture of acetone from kelp is manifestly a war time industry, so that potash as a by-product from this industry is not likely to survive the need of acetone for making smokeless powder.

BY-PRODUCTS OF OTHER INDUSTRIES

It has long been known that potash was among the volatile products passing off in the waste gases from a number of furnaces, notably from the rotary cement kiln and from the blast furnace. The writer made some experiments as far back as 1903 at the plant of the Dexter Portland Cement Co. to determine the effect which the ash of the fuel had on cement and particularly the percentage of ash which entered the cement in burning. Among other things which were disclosed by this investigation was the fact that there was a considerable proportion of both potash and soda volatilized in the rotary kiln. My investigations at that time were made on a 6 foot by 60 foot rotary and I found that approximately 50% of the potash was volatilized and about 25% of the soda. The results ¹ of the writer's experiments were given in a paper read at a meeting of the American Association of Portland Cement Manufacturers at Atlantic city in the summer of 1904, and also in his work "Portland Cement."

About this time Prof. Hillebrand, then of the U. S. Geological Survey, by analyses which he made in connection with the standard methods of analysis for cement and cement raw materials, found that the raw material contained relatively much more potash than the cement and he therefore assumed there must be some loss of potash in the burning of the cement.

Mr. Clifford Richardson ² read a paper at the 1904 meeting of the American Society for Testing Materials in which he proposed to the cement industry that they collect the potash lost by means of a water spray and stated that Dr. Hillebrand had applied for a

¹ Meade, Chemical Engineer, Vol. II, p. 221.

² Richardson, Trans. Am. Soc. Test. Mats., Vol. IV, p. 465.

patent upon such a process. We believe, however, that no patent was ever granted. The matter was discussed informally but it was generally conceded at that time that the cost of collecting this dust with the apparatus then known of, namely water sprays, would far exceed its value, if indeed it could be collected at all.

In Southern California, there had been considerable opposition from the orange growers to the cement plants owing to the dust from the kilns of the latter which settled on the orange groves and it was claimed impaired the value of the latter. Numerous suits were started and in order to try to appease the orange growers, the two plants near Riverside undertook to eliminate the dust at great expense. The California Portland Cement Co. in 1911 installed a system ¹ of dry settling chambers followed by water scrubbers at their plant at Colton and even prior to this the Riverside Portland Cement Company in their plant near Riverside installed a Cottrell electrical precipitation treater ² which latter was then largely in the experimental stage. The Riverside people persisted, however, in the use of this treater and gradually developed it into a very efficient method of catching the dust. By this means they were able to recover 95% of the dust lost from the kilns. It was found that in this dust was from 80 to 90% of the potash volatilized in the kiln. Unfortunately, however, the raw materials at that time in use at Riverside were quite low in potash and the dust obtained from the last part of the treaters averaged only about 4 to 5% potash, and that from the first part materially less than this, practically all of which was soluble in water.

In order to obtain a material richer in potash all of this dust was fed to a supplementary kiln and was burned to cement in that kiln. From this kiln, dust was obtained running in excess of 30% K_2O , but it was found that most of the potash in the dust fed into the kilns did not volatilize but remained with the clinker, due no doubt to the fact that the potash was present in the dust as sulphate.

When the fertilizer companies began to purchase low grade material for potash, one of the first substances which attracted their attention was the crust which collects on the side of the stacks of the rotary kiln and which falls down at intervals into the dust chamber, its high potash content having been pointed out by the writer in the paper mentioned above and also in his work on

¹ Hanna, *Trans. Am. I. Ch. E.*, Vol. VIII, p. 65.

² Schmidt, *Trans. Am. I. Ch. E.*, Vol. VIII, p. 35.

Portland cement. They persuaded a number of the cement manufacturers to save this crust which they purchased at prices ranging from \$1.50 per unit in the early days of the war to \$3.00 per unit later on. This dust averaged 6 to 8% of water soluble potash.

The Security Cement & Lime Company are among the cement companies who sold their flue dust. They were located near the heart of the fertilizer manufacturing district. Their manager, Mr. J. J. Porter, after seeing the installation of the Cottrell system at the first chemical show was very much impressed with the possibility of catching all of the dust from the stacks. He returned home and made investigations which demonstrated that they could expect to obtain quite a high percentage of potash in this dust. He then visited Riverside and investigated the process there and as the result of his investigation persuaded his company to install the Cottrell process, not with a view of eliminating the dust, as they were meeting no trouble from this source, but with the view to catching the potash at that time wasted. Their plant was put in operation in the summer of 1916. Numerous difficulties were encountered at the beginning, most of which have been satisfactorily eliminated, and the plant has been a great financial success, collecting from \$800 to \$1000 worth of potash daily.

One very peculiar situation presented itself which had not been foreseen. At the plant of the Riverside Portland Cement Company at Riverside, practically all of the potash in the dust was in the water soluble condition. When the treaters were put in operation at Security, it was found that only a little more than half of the total potash in the dust was water soluble and that while the dust contained from 12 to 15% total potash it contained only about 6 to 7½% of water soluble potash. The only explanation which could be offered to account for the difference in the state of the potash at the two plants is that at Security the cement is burned with pulverized coal and at Riverside with oil. It appears, therefore, that chemical combination takes place between the ash and the potash, both of which are in a state of extreme mechanical subdivision.

It is found, however, that all of the potash in the dust may be dissolved by prolonging the digestion with the hot water and by digesting under high pressure. It is also readily soluble in acid. In making mixed fertilizers with this dust it was found that a considerable portion of this potash was rendered soluble when the dust was mixed with acid phosphate.

It has, of course, been known that chlorides will increase the volatilization of potash. Numerous experiments were made at Security to increase the liberation of potash from the raw material and also to prevent its combination with coal ash in an insoluble form. One scheme tried was to inject sulphur dioxide into the kiln. The plan, however, which has proved most successful is to introduce a small amount of salt with the raw material and also with the pulverized coal. By doing this it has been found at the Security plant that they increase very materially not only the liberation of potash but also they prevent to an appreciable extent the recombination of the potash due to the saturation of the ash by the soda in the salt. When the treater was first placed in operation the average water soluble potash in the dust was about 6% but since the introduction of the salt, the quantity has been increased from $8\frac{1}{2}\%$ to 12% of water soluble potash. A patent has recently been granted to Huber and Reath (Nos. 1,194,344 and 1,219,315) who propose to use calcium fluoride in place of salt. They claim that the latter is entirely recovered by the treaters so that only a very small quantity of this mineral is needed, the original charge passing around in a cycle as it were. This process is in use at the Riverside plant and it is claimed 90% of the potash is volatilized where it is used.

The installation at Security was followed by one at the Duluth plant of the Universal Portland Cement Co. with a view to eliminating dust only. At this plant very little potash is obtained and I believe no effort is made to market the dust. This is due to the fact that slag which here takes the place of the clay element of the cement mixture contains practically no potash and consequently the amount of potash liberated is very small.

The Alpha Portland Cement Company have installed Cottrell treaters following boilers. That is the waste gases from their kilns are first led through water tube boilers and thence into the Cottrell treaters. At this plant, the percentage of water soluble potash in the dust is very low. The dust which they have obtained carries about 8% total potash, while only about $2\frac{1}{2}\%$ of this is water soluble. It was found that by the use of salt at this plant, the percentage of water soluble potash was increased very largely but unfortunately this salt collected on the tubes of the boilers and interfered with the steaming properties of the latter so that this treatment is not employed at this plant.

The Santa Cruz Portland Cement Co., Santa Cruz, Cal., have for the past ten months been experimenting with one of their kilns for the extraction of potash and have been making nearly 700 lbs. per day of potassium sulphate, 80 to 90% K_2SO_4 . The details of their process are not now available for publication but they do not employ the Cottrell dust precipitation system. They state that they consider their process a success and propose shortly to install their system on all their kilns.

At the present time installations of the Cottrell system are being made at quite a number of plants with a view to obtaining a dust high in potash which can be sold to the fertilizer trade.

The soda as well as the potash is volatilized to some extent so that the dust will contain some water soluble soda. Usually the proportions are about 1 to 4 or 1 to 3. When salt is used in the raw materials the proportions are much smaller.

As we said in the earlier part of this paper that practically all the potash in this dust could be slowly extracted with water it is highly probable that *all* of the potash in this material is available for plant food. In addition to the potash this material is rich in lime so that we have in this one material two very valuable fertilizer ingredients, lime and potash.

At the present time the fertilizer men are perfectly willing to take this dust carrying as low a percentage as 4% K_2O but it is extremely doubtful if they will accept it after the war is over and they can get German potash. The objections to the dust are two-fold, first it is of course highly alkaline containing both calcium carbonate and oxide. When used in mixed fertilizers in large quantity the lime reverts the phosphoric acid to the insoluble form. Second the dust is too low in potash to permit of its being used in fertilizers to contain more than 2% K_2O . Two propositions in this connection suggest themselves, one to educate the farmer to the use of this material as such and the other to extract the potash by leaching and evaporation and market the concentrated potash salt.

The Riverside Portland Cement Co. are so located that freight rates are against the sale of their potash dust and they have therefore placed in operation a process for leaching the potash out of the dust and they are now putting on the market potash salt containing 80% potassium sulphate. Their process as to its details is covered by patent No. 1,221,989 to Huber and Reath. The process for extracting the potash is as follows:

The dust is deposited from the treaters into cylindrical tanks 12 feet in diameter and 8 feet high which have been filled to a depth of about 6 feet, with water heated by means of live steam to a temperature of 85° C. The tanks are provided with agitators and the mass is continually stirred. After the dust is charged into the water this latter rapidly rises to the boiling point due to the hydration of the quick lime contained in the dust. The process is controlled by taking samples every few minutes, filtering and determining the specific gravity and percentage of dissolved solids. The whole operation of extracting the water soluble potash from seven tons of dust is accomplished in about 50 minutes. From the tanks the slurry is run by gravity into the reservoir under an Oliver filter press where its temperature is maintained at 85° C. by steam coils and the mixture is kept in motion by means of an agitator. The separation of the solids from the solution is affected by the Oliver filter press. The solution is stored in shallow concrete tanks which at the same time serve as an evaporating pond where under the influence of the very dry climate of Southern California, considerable evaporation takes place. When the liquid has attained a specific gravity of about 1.1 it is pumped to evaporating pans. As the solution becomes concentrated the salt drops to the bottom. It is then raked out on to drain boards where it is allowed to remain some minutes and thence is deposited in a hopper where the draining continues for several hours. From this hopper it is passed through a rotary dryer, thence through a Williams mill where it is reduced to the desired fineness and finally the potash salt proceeds to a bin over the sacking machine.

The writer in addition to experiments mentioned above has since the European war been able to examine samples of raw materials and clinker from some half dozen different plants. These samples all show that there is at most plants a loss of potash ranging from $1\frac{3}{4}$ lbs. to $2\frac{1}{2}$ lbs. per barrel of cement burned with an average of about 2 lbs. per barrel. It should be remembered that not all the potash so obtained, however, is water soluble, but it is all available for plant food and undoubtedly methods of leaching out the same can be easily worked out if found necessary. The efficiency of a Cottrell treater will range between 95 and 98% of the dust and 80-90% of the potash. When no treaters are installed the dust losses range from 3 to 5 per cent of the raw material introduced into the kiln.

At the present time the loss of dust at the average cement plant is probably in the neighborhood of 3% or 18 lbs. of dust per barrel of cement. If 95% of this dust and 80% of the potash at the present time lost is recovered, dust would be obtained having approximately 9% potash. Assuming that there could be recovered 1.6 lbs. of potash per barrel of cement there would be produced from the cement industry alone 72,000 tons of potash (figured as K_2O) per year or nearly one-third of the before the war importations from Germany.

The Bureau of Soils, Department of Agriculture, is at the present time preparing a very extensive report on potash possibilities of the cement industry and this report covers the subject of the losses of potash at various plants very completely.

About the time of the European war, I made a number of experiments in a small kiln 2 feet in diameter by 20 feet long to ascertain the possibilities of obtaining potash as a by-product from the cement industry, using feldspar, limestone and iron ore as the raw materials. If iron ore is not used, white cement would be obtained but it was our idea to come as near as possible to producing the product of most of the cement mills.

These experiments followed two general lines. At first, we furnished at about 800° C. a mixture containing salt or calcium chloride and lower in lime than would be used for cement, leached the resulting soft brown clinker with hot water to extract the potash, mixed sufficient limestone with the residue to make a proper cement mixture ground and burned the latter to cement. The second line of experiments consisted in making up a proper mixture for cement and burning the latter directly to cement, volatilizing the potash in so doing. We met with a fair degree of success along the second line. With the first process a number of difficulties were encountered. One was that with the best treatment we could give we could not render soluble more than about 60% of the total potash in the feldspar and that we lost some by volatilization. We found on analyzing the commercial side of the case that it seemed to be a much better proposition to attempt to volatilize all of the potash and make a cement clinker at one operation, particularly as we were able to volatilize about 70% of the total potash, whereas we were never able to render more than 60% of it soluble in the two stage process. Furthermore it required every little additional fuel to produce a cement than it did to produce the lighter burned

material and with the latter there was of course the extra fuel needed to burn it to cement. Owing to the large amount of water in the leached material this latter operation required more fuel than would be required to manufacture cement in the first place. To render the potash soluble we also had to use a considerable portion of either salt or calcium chloride, whereas if volatilized we used only a very small quantity of the latter. As an example of what we did along the line of volatilizing the potash: a mixture was made up of three raw materials, limestone, feldspar and iron ore. These three had the following composition:

	Limestone	Feldspar	Iron Ore	Mix	Cement
SiO ₂	1.02	68.12	16.20	13.40	20.80
Al ₂ O ₃	.40	19.05	1.88	3.78	5.86
Fe ₂ O ₃	.42	1.15	71.98	1.98	3.07
CaO	52.20	0.51	0.25	41.77	64.60
MgO	1.51	0.47	1.65	1.25	1.94
K ₂ O	.21	8.52	0.25	1.69	0.80
SO ₃					1.65

These three materials were mixed in the following proportions:

Limestone	800 lbs.
Feldspar	180 "
Iron Ore	20 "

These gave a mixture of the analysis shown in the fourth column and the final cement had the analysis shown in the fifth column.

This cement was found to have excellent physical properties and to compare favorably with any cement at the present time on the market. It was normal in every respect and would have been accepted by any engineer as first-class material.

By referring to the analysis it will be seen that the raw mixture contained 1.69% of potash. As it takes 600 lbs. of raw material to make a barrel (400 lbs.) of cement, there were charged into the kiln for each barrel of cement produced 10.14 lbs. of potash. As the clinker contained 0.80% potash there was in each barrel of cement 3.20 lbs. of potash, making a loss by volatilization of 6.94 lbs. per barrel. Assuming a dust loss of 3% or 18 lbs. per barrel this dust should contain 38.56% K₂O.

The potash volatilized at various plants as I have said varies quite

widely, ranging from 1.5 to 2.5 lbs. At plants where the former amount is lost recovery would probably give a dust too low in potash for sale in this form. At such plants, recovery would have to be followed by leaching. Experiments which we have made convince us that this can be successfully done if proper means are installed. This would give a residue which could be used in the kilns and the potash would be in the form of a salt running 60%-80% K_2SO_4 .

It should also be borne in mind that there is always the possibility of increasing the liberation of potash by selecting raw materials high in potash. No doubt in many localities a change of clays from one low in potash to one higher would bring about the desired result. In many localities feldspar and sericite are available and might be mixed in with the clay to increase the potash without detriment to the cement. Indeed as I have indicated above feldspar and iron ore might take the place of clay, or if a white cement is desired feldspar alone might be used. At the Riverside plant, feldspar is mixed with the shale to increase the potash in the raw material burned.

The possibilities of developing a paying potash industry in connection with the manufacture of cement are excellent. Unfortunately for the speedy establishment of such an industry, the very high cost of steel plate and structural steel at the present time will undoubtedly keep many manufacturers from installing plants who would otherwise do so. The question too is not alone one of price but also of deliveries. No manufacturer would care to pay the present high price of steel without assurance that he would also enjoy the present high price for potash. Under normal conditions a treater plant for precipitating the dust from a 3,000 bbl. per day cement mill will cost about \$100,000 complete or 10 cts. per barrel of annual output, but at the present time the cost will be fully twice this amount.

The dust question has always been one of more or less annoyance and the chance to settle this once for all and at the same time obtain a valuable product will certainly appeal to the cement industry. In addition to the treaters I believe that most manufacturers will install boilers behind their kilns, saving the waste heat from the latter, which is normally more valuable than the potash. The two installations work very nicely together as the flues, dampers, fans, etc., of one installation will serve for the other and the boilers will cool

the gases enough to permit of very much smaller treaters being used, since the treaters required are proportional to the volume of gases to be cleaned. The cost of boilers and treaters normally will be about 15 to 18 cts. per barrel of annual output and now from 30 to 35 cts. per barrel.

If many cement manufacturers would install boilers and treaters even now with the present high cost of materials and could sell their potash for \$3 per unit for a year, they could pay for their plants.

I estimate it would cost now approximately \$30,000,000 to equip all the cement plants in this country where such installations would pay with boilers and treaters and that for this outlay we would save annually even in normal times.

72,000 tons of K_2O	@ \$80 per ton	\$5,760,000.00
2,400,000 tons of coal	@ \$3 per ton	7,200,000.00
Total Saving		\$12,960,000.00

Even after deducting the cost of operation, upkeep, etc., this would pay a very handsome interest on the investment.

The loss of alkalis in the blast furnace has been known for many years but no efforts had been made to recover potash up to the outbreak of the war. Mr. R. J. Wysor, then chief chemist but now superintendent of blast furnaces of the Bethlehem Steel Co., previous to this had analyzed the dust from the bottom of the stove checkerwork and found it to contain 15% water soluble K_2O . Attempts to sell this material prior to the war failed but with the demand induced by the war it was found readily salable and has been collected and sold ever since.

Mr. Wysor has since that time made a very extensive study of the possibilities of potash recovery from the blast furnace gases at Bethlehem. The result of his investigation is given in a paper ¹ read at the February meeting of the American Institute of Mining Engineers in New York, and most of the information given below is taken from his paper.

The ores used by the majority of iron manufacturers range from 0.21 to 0.33% K_2O . A notable exception is the Mayari ore of Cuba which contains very little K_2O . Some of the southern iron ores contain much more, but generally speaking these are high

¹Bul. Am. I. Min. E. Jan. 1917 p. 1.

in clay and hence would naturally contain feldspar. Coke generally contains about one-quarter per cent K_2O and limestone varies from a tenth to nearly one per cent K_2O . The impure limestones high in clayey matter usually contain most K_2O and dolomites generally speaking are higher in K_2O than are calcites.

Wysor found in the Bethlehem charge 22 lbs. of potash per ton of pig iron produced of which about half came from the ore and a quarter each from the limestone and coke. He found that 20% of the potash remained in the slag and hence 80% was volatilized. Of the latter he estimated that about seven per cent was lost in fumes escaping at the cinder notches, from the top of the furnace, etc., leaving about 73% which could be recovered. Of this 73% by far the largest amount is lost in the wet scrubbers, which remove 58% of the potash, the latter going into solution in the water used to wash the gases. The solution is too dilute, however, to permit of the recovery of the potash by evaporation. Wysor estimates that it is possible to recover about half of the total potash lost by dry cleaning of the gases, using a Cottrell treater instead of the wet washers. Up to the present time only about 4% of the total potash has been recovered and sold yet the amount of dust so recovered in 15 months has amounted to 106.3 net tons of K_2O . It represents only the dust most easily collected at the stoves and boiler flues and dust catcher. This dust averages about 9.9% water soluble potash. The dust, unlike that from the cement industry, is not highly alkaline. It is probable that after the war leaching would have to be resorted to.

As in the cement industry certain advantages other than the recovery and sale of the product are connected with the removal of the dust from the gases, notably the better cleaning of the gases.

It seems very probable that the dry method of cleaning will replace the wet at many furnaces which would result in the saving of much potash. Assuming a recovery of 10 lbs. of potash per ton of pig iron and an annual production of 25,000,000 tons of pig iron, the potash resources of the iron industry would be 125,000 tons of potash figured as K_2O annually.

Our former imports from Germany averaged about 250,000 tons K_2O annually, so it will be seen that the cement industry and the iron industry alone might be developed to produce nearly 200,000 tons annually.

The cost of operation of the dry treaters would probably prove

less than that of the wet washers now used for cleaning blast furnace gases, so that the only added cost of potash recovery would be the labor of collecting the dust, leaching, etc., and the fuel for evaporation of the liquid and drying the salt, which items would be about the same as for the cement kiln dust.

The production of potash from the waste liquor of beet sugar manufacture, molasses, etc., has been treated of in a paper which is to be read at this meeting so that it is hardly necessary for me to go into this subject at this time. It is estimated that about 2,000 tons of potash (figured at K_2O) are now being produced annually from this source, one of the largest producers being the Western Alcohol Products Co., of Agnew, Cal., and it is said that their output is larger than that of any of the kelp plants on the Pacific Coast.

FROM ALUNITE AND SILICATE ROCKS

Alunite is a hydrous sulphate of alumina and potash containing about 9% potash. So far it has been found in workable quantity only at Marysville, Utah. Two concerns are working on this mineral, the principal operator being the Mineral Products Corp. The Florence Mining & Milling Co. also mine, calcine and sell alunite but do not extract potash salts. The former concern operates the Chappell process in which the ore after crushing is heated in a rotary kiln to $750^{\circ}C$. and the potash extracted with water. From this solution the potash is obtained by evaporation. The equipment of the plant is modern, comprising in part rotary kilns, Kelley filter presses, multiple effect evaporators, dust precipitators, etc.

A number of other concerns have been incorporated with the purpose of engaging in the production of potash from alunite.

The deposits of alunite are comparatively limited and are in the hands of a few people. It seems hardly probable in view of the slow progress which has been made to date that this mineral will ever be the source of anything more than a small local potash industry.

The production of potash from silicate rocks has been the subject of much chemical investigation and the patent offices of England, Germany and the United States have granted many patents on process looking toward this end. One of the oldest of these was granted to F. O. Ward and F. Wynants (English patent No. 3185) in 1857. This process is said to have been tested at that time on

a large scale and to have given satisfactory results. It consisted in finely grinding and mixing feldspar, fluorspar and chalk and after moulding the mixture into balls or cakes heating these to a yellowish red heat. A porous clinker was obtained which on leaching with hot water gave up its alkali. It is interesting to note that Ward even at that time proposed to use the residue from which he had leached the potash for the manufacture of hydraulic cement.

It is quite natural that the chemical principles made use of by Prof. Lawrence Smith to attack silicates in his method of determining the alkalies should have been the subject of much investigation looking towards their application to the liberation of potash from feldspar and other silicates on a large scale; and many patents have been granted making use of the essentials of his methods of attack but varying the reagents and procedure so as to apply more directly to practical work.

One of the earliest of these patents was that granted to Rodin (U. S. No. 641,406). He used a mixture of powdered feldspar, salt and lime. This patent has been followed by a large number of others granted for various modifications of the same general scheme in which gypsum, calcium chloride and other haloid compounds took the place of the salt. Nearly all of these processes make use of lime in connection with the above reagents.

Along a somewhat different line we have another series of patents, the first of which was issued to A. J. Swayze in 1905 (No. 862,676). He proposed to fuse feldspar, gypsum, coal or coke in a blast furnace whereby potassium sulphates would be volatilized. Other patents along this line are those issued to H. E. Brown (U. S. Nos. 1,123,841, 1,123,864 and 1,124,238). Just recently issued we have a whole series of patents to A. C. Spencer and to Spencer and E. C. Eckel covering the volatilization of potash and the production of hydraulic cements (U. S. Nos. 1,209,220, 1,209,219 and 1,209,135).

In addition to the above general line of patents we have many in which novel methods of attack have been proposed and in which various valuable by-products would be obtained which would assist in paying for carrying out the process.

It has generally been conceded that to make potash alone from feldspar was an almost impossible undertaking under normal conditions and pre-war time prices for potash. The reason for this may be readily understood when we take into consideration that feldspar

as ordinarily mined, without careful sorting and selection, very seldom runs over 10% potash and frequently as low as 8%. At a price of 80 cts. a unit, this would allow only \$6.40 to \$8.00 for the mining or quarrying of the feldspar, its crushing and grinding, the reagents which are to be used with it and the fuel and labor necessary to liberate the potash. In view of the fact that it is generally conceded that feldspar mining will cost approximately \$2.00 per ton, we have only \$4.40 to \$6.00 left to carry on the rest of the process and furnish overhead and profits.

A very much cheaper source of potash than the feldspar is the green sand or glauconite of the Atlantic Coastal Plain. The deposits of this mineral are very extensive and the quantity obtainable is probably greater than that of any potash mineral. My own observations of the New Jersey field has convinced me that green sand can be found in many localities in New Jersey containing as much as 6% potash. These beds range from a few feet to 20 feet in thickness. They are covered with very little overburden and the material can be dug with a steam shovel just as cheaply as sand can be obtained. I estimate that 10 cts. per ton will cover both stripping and digging the green sand. In addition to this there are adjacent to the green sand beds extensive deposits of lime sand or marl. This latter contains about 75 to 85% carbonate of lime and about 0.5 potash. In many instances the lime-sand overlies the green sand. These deposits are also located in a region where fuel is fairly cheap, where transportation facilities are of the very best and where labor and living conditions are good. In view of these facts it seems to be much more probable that potash can be produced directly from green sand at a profit than from feldspar.

Most of the other silicates such as leucite and sericite are of comparatively rare occurrence. They can be treated more or less along the lines of attack proposed for feldspar and glauconite.

Referring to the various processes proposed, considerable experimental work, some of it on a large scale, has been done on those in which lime and a chloride are mixed with feldspar or green sand and the mixture is ground, furnaced, leached and the resulting liquor evaporated and the potash so obtained. Mr. W. H. Ross of the Bureau of Soils published a very interesting paper along this line in 1912, giving the results which he was able to obtain by heating together a mixture of feldspar, limestone and either calcium chloride or salt. He found that unless he used quite a large pro-

portion of lime and chloride that his yields were low, his best results being obtained on a mixture of one part feldspar, three parts limestone and one-half part calcium chloride, under which condition he obtained a yield of almost 95%. But with a mixture of one part feldspar, one part lime and one-quarter part calcium chloride, he obtained a yield of only 60%. Substituting salt for calcium chloride in the latter mixture, however, he obtained a yield of 68½%.

Following along practically the same lines, and using a mixture of one part feldspar, one part calcium carbonate and one-quarter part calcium chloride, heating this mixture in a rotary kiln 2 feet in diameter and 20 feet long, I obtained a yield of 55% potash. By substituting salt in place of the calcium chloride a slightly better yield was obtained. As the amount of lime was decreased from the above formula, less potash was obtained. The more finely the mixture was ground the better results were obtained also, but the best yield I could get with feldspar, lime and salt in the proportions given above when the mixture was ground to a fineness of 98% passing the No. 100 mesh sieve and 86% passing the No. 200 mesh sieve, was 73%. This was considered about the limit possible to grind the mixture economically in practice. Substituting sericite for feldspar I obtained practically the same yield but with glauconite I was able to obtain a much higher yield and in fact all investigations which I have made lead me to believe that this mineral is very much more easily attacked than feldspar. With the glauconite-lime-salt mixture referred to above we have obtained yields as high as 85% of the potash theoretically possible.

Referring again to the practical features of this process it is a very easy one to carry out. The operation of crushing and grinding the material have been well taken care of in the cement and various metallurgical industries and the furnacing can, of course, be done in a rotary kiln. No complications are experienced in this latter operation. The temperature is low and either producer gas, pulverized coal or fuel oil could be used. In my experiments for convenience I used the latter fuel. I do not believe any complication would arise from the use, however, of pulverized coal and certainly not from producer gas. The material furnaces easily at temperatures varying from 800 to 1000° C., depending on the composition of the mixture. No fusion takes place, the effort being made to produce a soft porous clinker. This latter leaches easily without

grinding and 95% of the soluble potash in it can be extracted with water. The amount of fuel required in the kiln is much lower than that used in the manufacture of cement and certainly should not exceed for the dry process more than 250 lbs. to the ton and for wet process 350 lbs. to the ton. Any loss by volatilization can be taken care of by Cottrell treaters.

By leaching in series very strong solutions can be obtained so that the amount of water to be evaporated is cut down to a minimum. Potassium chloride can be separated easily from either calcium chloride or sodium chloride and the latter can be returned to to the kilns with the next charge.

On the other hand if the sulphates are used to attack, a difficult separation nearly always results so that while there is probably less volatilization with the sulphates, there is much more difficulty experienced in obtaining a pure potash salt and as it is well known, the chloride is the most acceptable salt for chemical manufacture.

Strange to say, very few attempts have been made to produce potash commercially by this process, possible because it has not promised anything like the returns which some of those other processes do in which by-products are obtained.

The Atlantic Potash Co. recently bought out the plant of the old Northampton Cement Co. at Stockertown, Pa., which had been standing idle for some time. They are operating under the patents granted to Geo. F. von Kolnitz (No. 1,201,396). This process consists in oxidizing the green sand and heating the same with calcium chloride without the use of lime. This plant is now in operation and we understand that some potash has been produced.

Along the second line of patents referred to above in which the potash is volatilized, we have the three granted to H. G. Brown and covering the manufacture of potash and slag cement from feldspar. Brown proposed to fuse together limestone, feldspar and calcium chloride in a metallurgical furnace heated with coke. The potassium chloride is given off as a fume which is to be collected by a Cottrell treater. The slag which is tapped off is to be mixed with slaked lime and ground into slag cement. The Buffalo Potash and Cement Corp. will operate this process. They purchased the plant of the Niagara Cement Company in Buffalo and I believe expect soon to be ready to operate.

We also note in recent literature the organization of the Canadian Potash Corp. which proposes to manufacture potash and ce-

ment along somewhat similar lines. They have purchased a crushing plant at Gravenhurst, Ont., where there is a large deposit of feldspar, and also a cement plant at Durham, Ont.

While we are disposed to criticize the cement end of these propositions so far as they anticipate making slag cement, the potash end looks entirely feasible and if it can be operated independently of the slag cement production, it may be developed to any extent desired. Slag cement at the present time is not a very salable product and we believe that practically all of those who first undertook its manufacture in this country have now abandoned it.

Another method of liberating potash is covered by patents to S. Peacock and consists in heating the finely ground mineral with lime under pressure in an autoclave whereby the potash is made soluble and is leached out. The Waverly Chemical Co., Camden, N. J., operated under these patents and Dr. Peacock's supervision, using green sand. They made some potassium carbonate which was sold to glass makers but their operations have now been discontinued, presumably because they could not be conducted at a profit.

The Kaolin Products Co., Jones Point, N. Y., is using this same process in a small way, employing feldspar, however. They make a species of sand lime brick from the residue from which the potash has been extracted. This brick I am informed is a very superior article.

Furman Thompson proposed to employ acid sulphate of soda and salt to attack feldspar (U. S. Pat. No. 995,105 and also No. 1,091,034 to H. P. Basset). Muriatic acid and salt cake are obtained as by-products. The Spar Chemical Co., Baltimore, Md., built a plant at Curtis Bay, Md., prior to the war to produce potash by this method but their efforts here failed due largely to the difficulty of separating the sulphate of soda and potash.

We now come to a series of patents most of which are dependent on some valuable by-product for their success with normal markets. For instance we have the patent of Hart in which barium carbonate, carbon and feldspar are fused together and barium sulphate or other barium salt is obtained as a by-product. The application of this patent is of course limited to the market for barium compounds. There are also a large number of patents in which aluminium salts are obtained as by-products. As there is about twice as much alumina in feldspar as potash as ordinarily mined, there would of

course be a very large tonnage of alum or alumina to get rid of if it is desired to obtain any great quantity of potash.

For instance, feldspar averages say 20% alumina and 10% potash, therefore for every ton of potassium chloride produced, there would be possible $4\frac{1}{4}$ tons of dried aluminium sulphate or $8\frac{1}{4}$ tons of dried alum. The amount of potash used in this country of course far exceeds the amount of alum. If we consider the aluminium in feldspar on the basis of bauxite used, the raw material for aluminium as well as alum and of which the domestic production is about 225,000 tons annually, we can arrive at a better estimate as to the limitation of this field. Bauxite averages say 57% alumina, then the above amount is equivalent to 128,250 tons of alumina, which would take care of about 102,000 tons of potassium chloride or 64,000 tons of potash.

In many of the processes proposed, the quantity of potash is very negligible compared with that of the by-product, and generally under normal conditions its value is much less, so that with most of them, potash is really the by-product and the other constituent the main one.

Summing up the situation, I believe that the largest future source of cheap potash available in this country is in the iron industry and the cement industry. Germany is reported to have \$150 invested in her potash mines and equipment for every ton of potash produced annually. On this basis to produce the 250,000 tons of potash imported into this country, would be needed \$37,000,000. I believe that the expenditure of this amount of money in this country in these two industries alone would result in the recovery of potash now lost amounting to nearly 200,000 tons. The balance could easily be obtained from the evaporation of lakes and brines, from beet-sugar waste and from some of the processes now proposed for the manufacture of potash direct from feldspar or glauconite.

What is most needed in this country to develop a potash industry is not research alone but the feeling that when this industry is built up, proper legislation will be enacted to prevent its being tumbled down by cut-throat methods from the foreign producer. While this protection might result in slightly higher priced potash to the farmer, I fully believe that he will be justified in paying the higher price in order to be free from foreign dictation.

A NEW METHOD FOR THE RECOVERY OF SALTS OF POTASSIUM AND ALUMINIUM FROM MINERAL SILICATES

By J. C. W. FRAZER, W. W. HOLLAND and E. MILLER

Read at the Buffalo Meeting, June 22, 1917

A great many efforts have been made to obtain salts of potassium from such silicates as sericite and orthoclase. These minerals are not attacked by acids. The feldspars occur widely distributed and are the most abundant of all minerals. Orthoclase feldspar of a sufficient degree of purity occurs in such quantities as to make it a possible source of supply of potassium salts.

Owing to the fact that in normal times potassium salts can be obtained very cheaply from Germany, and, also to the further fact that such silicates as feldspar and sericite can be decomposed only with difficulty, any process for the successful treatment of such silicates must obtain by-products of value in addition to the potassium.

A great many patents have been obtained on processes for the treatment of feldspar. Most of them make use of very high temperatures and rely in many cases on the separation of the potash by volatilization. The greatest objection to such processes is that in addition to being expensive it is difficult to separate the potash from the other constituents after the silicate has been decomposed.

I wish to call your attention to the results of some experiments which were made last year in our laboratory for the purpose of making available the potassium and aluminium contained in such silicates as feldspar and sericite.

It was soon realized that for any such process to be successful all the constituents of the silicate must be recovered in valuable form and at a minimum expenditure of energy and cost. The truth of these statements is borne out by the great number of unsuccessful attempts which have been made recently to obtain potash from feldspar.

On this account it was decided to avoid, if possible, the method so frequently resorted to by others, of bringing about complete

decomposition of the mineral, for by operating in this way a resort to high temperature is avoided, which adds to the cost of operation and leads to final products, many of which are useless or can be separated only with difficulty.

The method finally adopted secures the transformation of feldspar by successive stages into products analogous to certain well defined minerals occurring in nature. It is well known that most of the "available" potash which occurs in the soil comes from the weathering of feldspar. This so-called weathering process takes place slowly in nature and the final products of this reaction is a hydrated silicate of aluminium known as kaolinite ($\text{H}_4\text{Al}_2\text{Si}_2\text{O}_9$).

In addition to kaolinite there are certain minerals such as leucite which are intermediate in composition between feldspar and kaolinite though they probably do not appear in the course of the weathering process. The important difference between the feldspars and leucite is, that whereas feldspar is not attacked by mineral acids, leucite is easily decomposed under these circumstances giving salts of potassium and aluminium and liberating silica.

Our experiments soon showed that an alteration of feldspar to a substance analogous in composition to leucite could be secured by treatment of feldspar with a strong alkali under conditions given more in detail later on. This reaction possesses for our purpose two distinct advantages: (*a*) it is one very easily brought about when the proper conditions are obtained; (*b*) the product of the reaction possesses the convenient property of fractional decomposition when treated with dilute mineral acids.

METHOD

A quantity of finely ground feldspar (about 50 mesh) is brought into contact with about 8/10 its weight of potassium or an equivalent amount of sodium hydroxide dissolved in a small quantity of water in order to obtain an intimate mixture of the two. The mixture is then heated in an open iron vessel until the water has evaporated and thereafter for a period of about one hour at a temperature of $275\text{--}300^\circ\text{C}$. During the latter stage of heating a reaction takes place between the alkali and the feldspar which consists essentially in the withdrawal by the alkali of one of the three silicic acid residues of the feldspar, forming a new

silicate and an equivalent quantity of alkali silicate. This new silicate when completely dry has approximately the composition of leucite ($\text{KAlSi}_3\text{O}_8 + 2\text{KOH} = \text{KAlSi}_2\text{O}_6 + \text{K}_2\text{SiO}_3 + \text{H}_2\text{O}$). It is insoluble in water and may be separated from the soluble portion, which consists of the excess alkali used for the decomposition and the alkali silicate simultaneously produced.

The alkali employed in bringing about this reaction which is now in solution, part as hydroxide and part combined with the silica removed from the feldspar, can be entirely recovered by causticizing the solution with lime and filtering off the calcium silicate which is precipitated. This solution, when evaporated, is used for the treatment of other, fresh portions of feldspar, the only loss being the unavoidable mechanical losses which in our laboratory experiments performed on one kilogram lots amounted to about one per cent.

The "artificial leucite" which contains all the potash and alumina and $\frac{2}{3}$ of the silica of the original feldspar can be made to yield its constituents one at a time by proper treatment with acids thus avoiding expensive methods of separation by evaporation, crystallization, etc., the corresponding salts of potassium and aluminium being produced in succession. The basis for this treatment is the fact that the potassium contained in this new silicate is very much more loosely held than is the aluminium.

This can be illustrated in a number of ways. By suspending some of the silicate in water between two platinum electrodes one can, on passing the current, bring practically all the potassium from the substance into solution as the hydroxide. Or the solid substance suspended in water can be titrated with a mineral acid and methyl orange as an indicator and with sufficient time towards the end of the titration a fairly satisfactory end point can be obtained. The method of separating the potassium from this so-called artificial leucite is based on this fact and the method of utilizing this property of the mineral for removing the potash is quite simple. The fact that the potassium in the silicate can be titrated with a fairly good end point shows that the hydrogen ion concentration of the solution necessary to bring this about is very small. Any mineral acid will serve the purpose and it is therefore possible to obtain the potassium directly as chloride, sulphate or nitrate without the removal of the aluminium. Ordinarily we have used hydrochloric acid for this purpose as most of the potash has been

imported into the country as chloride. For this extraction the silicate is mixed with water, and dilute hydrochloric acid in amount equivalent to the potassium content of the silicate is added slowly with constant stirring. The only thing to be avoided at this point is a local excess of acid which would tend to bring into solution a portion of the aluminium. The potassium chloride solution is removed from the insoluble silicate of aluminium by filtration. The silicate of aluminium which remains is somewhat analogous to kaolinite, the final product of the weathering of feldspar. The separation of the aluminium from silica in this silicate is comparatively easy because of the readiness with which mineral acids effect its decomposition. If this silicate is treated with an amount of sulphuric acid equivalent to the aluminium it contains aluminium sulphate is produced and gelatinous silica separates. As it is necessary to render this silica insoluble by evaporation, the sulphuric acid employed for the decomposition will not be very dilute. After dehydrating the silica the aluminium sulphate is dissolved in water and separated from the silica by filtration.

The same product is obtained by the treatment of other silicates such as sericite and clay.

The recovery of the products by this method is about as follows: The yield of potassium chloride is practically theoretical, the yield of aluminium sulphate is about 86% of the theoretical. On a feldspar running 10% K_2O one would contain about $\frac{1}{4}$ of a ton of potassium chloride of 80% purity which is the grade usually imported for commercial purposes, and about one ton of crystallized aluminium sulphate. By a consideration of these figures it will be seen at once that in normal times the aluminium sulphate is more valuable than the potassium chloride produced and under these conditions the process is an aluminium sulphate process with potash as a by-product. There are certain advantages in this since the importation of cheap German potash after the war would effect the process less than it would if potassium chloride were the principal product. For these reasons the value of the process in normal times will depend largely on the cost of producing iron free aluminium sulphate by this method as compared with the method now used in making it from bauxite.

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THE RECOVERY OF POTASH FROM BEET-SUGAR HOUSE WASTE LIQUORS

By H. E. ZITKOWSKI

Read at the Buffalo Meeting, June 22, 1917

The recovery of the residual values from beet-sugar waste liquor has been the subject of serious investigation even prior to the war. However, the abnormally high potash prices of the past few years have brought about renewed efforts in this direction.

The fundamentals for a consideration of this problem are the following:

During the 1916 season approximately 6,000,000 tons of sugar beets were produced in the United States. In all probability a materially greater tonnage will be produced this year, and the possibilities for increased production in the immediate future are promising, though this phase of the problem is so intimately related to the tariff, the agricultural labor supply, and ruling prices of other agricultural products, that prophecy is fruitless.

The composition of the beet, and therefore its content of potash, is variable from season to season and in different localities and soil conditions. The following analyses of beets from three widely separated localities in the United States can serve as a basis.

	Colorado	California	Wisconsin
Moisture	78.36%	63.99%	74.37%
Dry Substance	21.64	36.01	25.63
Ash (Carbonate)	.89	.88	
Total Nitrogen	.199	.254	.1817
Sugar	15.40	25.60	18.7

Mineral matter in per cent on beets:

Cl	.102	.065	.040
SO ₃	.028	.034	.024
P ₂ O ₅	.046	.121	.023
K ₂ O	.320	.269	.320

Na ₂ O	.097	.106	.089
CaO	.032	.078	.041
MgO	.058	.051	.047
Fe ₂ O ₃ Al ₂ O ₃	.042	.014	.027
SiO ₂	.005	.016	.036

Both the California and Wisconsin sample were several days in transit to the laboratory at which the analyses were made, and undoubtedly lost considerable moisture by evaporation which consequently increased the percentage content of dry matter. Aside from that the California sample was abnormally high in sugar content.

From an agricultural and economic viewpoint—aside from the sugar—the nitrogen, phosphoric acid and potash content of the sugar beet is of more than passing importance.

Accepting the average of the three analyses herein reported as the average for the entire production, the 6,000,000-ton crop of beets of 1916 contained of

Nitrogen	12,700 tons.
Phosphoric anhydride	3,780 "
Potassium oxide	18,180 "

Investigations indicate that in extracting the sugar values by the diffusion process approximately 60.0% of the nitrogen and 90.0% of the phosphoric acid and potash content are extracted with the sugar and pass into the process; the rest remains with the pulp. As this pulp now is completely utilized for live stock feeding purposes, the plant food values of this pulp are not lost to agriculture except in so far as farmyard manures are inefficiently utilized.

Of the plant-food values extracted and now in the juices, phosphoric acid is completely eliminated as calcium phosphate, and to date largely wasted. A part of the nitrogen content is eliminated as coagulated protein and otherwise, together with the phosphoric salts. The potash, however, is not eliminated from the juices by the usual processes of purification and is found in the final molasses, that is the mother liquors, from which sugar cannot be further recovered by direct crystallization, and for this the presence of potash salts are partly responsible.

The production of molasses from beets is somewhat variable from season to season, but an average percentage production for the United States will be somewhere between 5.5% to 6.0% on beets. With a six million ton crop of beets this totals to 330,000 to 360,000 tons.

A study of a series of thirteen samples of American Beet molasses as reported in Volume 18, No. 4, of Sugar, indicates an average content of 1.69% nitrogen and 4.66% of potassium oxide, K_2O .

On this basis the sugar-beet molasses production of the past campaign contained between 15,400 and 16,700 tons of K_2O , which checks fairly closely with the figures above estimated. Of the total beet molasses production, under normal conditions, perhaps 5.0% under present conditions double this amount or more, is used in alcohol production and the still residues, containing the potash, are concentrated and usually enter the fertilizer trade and are therefore not lost to the general economy.

Approximately 40.0% of the total molasses production is used for stock-feeding purposes, in part direct as such, but by far the greater part is mixed with some absorbent feed, frequently beet pulp either fresh or dried, and also many of the fodders. The potash values in this case are recovered in proportion as the manure values from these feeding operations are recovered.

The remainder of the United States molasses production, perhaps 45.0% of the total, during the past season from 148,000 to 152,000 tons, is desugarized; that is, sugar is extracted in marketable form. It is this portion of the beet crop that contains the possibilities of potash production in commercial form at the sugar factories.

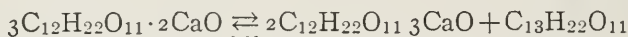
The process now used almost exclusively in this country in extracting sugar from this molasses is known after its inventor, as the Steffens precipitation process in which sugar is precipitated as tri-calcium saccharate.

Essentially the procedure is as follows:

Molasses of about 80.0% solids is diluted to 10% to 12% solid content, cooled to about 15.0° C., and under suitable means for cooling and stirring, finely powdered calcium oxide is dusted into the solution. If the conditions essential to the process are adhered to 90.0% or more of the sugar is precipitated as a calcium compound and is removed from the mixture by filtration.

The filtrate, now with a content of solid matter of 5% to 7.0% contains practically all of the potash originally in the molasses and also variable percentages of sugar not precipitated above.

The sugar in solution is probably present in the form of di-calcium saccharate $C_{12}H_{22}O_{11} \cdot 2CaO$. If this cold filtrate is heated to 85° C. approximately 60.0% of the sugar in solution is precipitated as a calcium saccharate according to the following reaction:



The reaction is reversible and on cooling the saccharate formed dissolves. It is necessary to filter at the precipitation temperature.

This, known as the Hot Saccharate process, is now quite generally used to recover additional sugar values from the solution which are not readily and economically recovered by the first step or cold process.

The filtrate, now known as Steffens hot waste water, still contains from a few hundredths to four or five-tenths of a per cent of sugar, some lime and practically all of the potash and most of the other non-sugars present in the molasses. This is the waste liquor forming a potential potash supply.

In several instances, where the sugar company controls agricultural lands in quantity adjoining the factory, these waste liquors, together with other residues, are used to irrigate the lands. This is perhaps the most economical method of utilizing the residual values as all of the potash and phosphoric acid and nearly all of the nitrogen of the beet can be returned to the soils, but this is practical only in isolated instances, and only about 8.0% of the total beet crop is handled in this manner.

In still other of the irrigated sections where the residual waters are discharged into existing streams and the streams are subsequently diverted for irrigation purposes some of the values may be inadvertently utilized, but in any event the losses to the economy of the state must be very considerable by this method of disposal.

In most cases the waste residues are sent into settling basins, the clear effluent of which reaches the streams and is carried away. Efforts had been made even before the war to recover these values, and owing to the stimulus of high potash prices of recent years the work in this direction has been followed with more than usual vigor. However, the problem has its difficulties.

As the hot waste water as produced is very dilute containing 96.0% or more of water, it is necessary to concentrate it. As produced it contains .2 to .5% of free lime, CaO , which will foul the evaporating surfaces if not removed. This is readily enough accomplished by carbonating (injecting CO_2 gas) and filtering. (It might be stated that during the past campaign in one case these waters were concentrated by the direct gases from an oil fire passing upward through a sheet metal gradier over which the waste liquors flowed. In this case removal of the lime was not necessary as the heat transfer was brought about by direct contact without an intervening metallic surface. This method of evaporating is prohibitive as to costs under normal conditions.)

The carbonated and filtered waste water varies in composition with the season, locality, and factory practice, but the following is typical:

Moisture	97.00%
Dry Substance	3.00
Carbonate Ash	1.00
Sugar	.30
Organic non-sugar	1.70
Nitrogen	.16
K_2O	.35

This indicates at once that the content of values is low, the cost of evaporation comparatively great, and also that, under normal conditions, when the value of a unit of nitrogen is two or three times that of a unit of potash, the nitrogen values are as great or greater than those of the potash contained in these waters. Up to a content of 50.0% to 55.0% dry substance this water can be readily enough concentrated in multiple effect evaporators, and quadruple and also quintuple effect evaporators, have been used very successfully. With a content of more than 55.0% dry matter the liquor begins to salt out and foul the heating surfaces. However, beyond this point the material can be readily enough concentrated still further and brought to a dry state by the use of one of the various types of Vacuum Drum Dryers. The trouble is to keep the material dry.

The dried material containing 10 to 12% of K_2O and 5.0% N. is so exceedingly deliquescent and absorbs atmospheric moisture so readily that it becomes fluid in a very short time.

Various absorbents have been used to overcome this difficulty, one of the most successful being dried slaughter-house wastes, which incidentally are deficient in potash, so the two materials complement one another. Ultimately this may prove to be a direction in which considerable quantities of the sugar factory waste waters will be utilized, but unfortunately very few beet sugar factories are now located within a reasonable distance of the meat packing centers and the cost of freight enters.

In some localities small quantities of 50-55.0% dry substance have been disposed of in tank car lots directly to the agricultural industry as a liquid fertilizer. In other instances it is urged to sell the liquid fertilizer direct to the farmer, the farmer to saturate his barnyard manure with the concentrate and thus use it. It is doubtful whether material quantities can be disposed of in this form at present.

With present potash prices the nitrogen values have lost their relative value with the result that in at least one instance these have been sacrificed in order to obtain a product comparatively high in potash content, which would permit its shipment considerable distances to the potash consuming centers.

When the Steffens water is concentrated to about 55.0% dry substance owing to its high content of sugar, and other organic matter, it can be quite readily ignited and charred, its own content of combustible matter then furnishing the most of the necessary heat. The char, or crude ash thus produced contains from 30 to 35.0% of potassium oxide, but only traces of nitrogen. This procedure is economically justifiable only with present potash prices. In other directions experiments are being made towards a recovery of the potash salts in comparatively pure form, and still save the nitrogen values.

That roughly covers the efforts made in the recovery of the values of the beet sugar liquor residues.

Technically the recovery of the potash values from these liquors is a comparatively simple and perfectly feasible problem. It is simply one of evaporating the dilute liquors as economically as practical, charring the residue to produce the crude ash and leaching and recrystallizing if this is desired. The quantities of water to be evaporated, however, are large, the necessary equipment costly, and commercially such a procedure has possibilities only during war prices.

Now it is true that almost any sugar factory could have paid for a potash recovery plant in one year with present potash prices, but the war may end any time and leave a lot of very costly equipment on hand, especially as the cost of such equipment, evaporators, boilers, etc., is abnormally high at present. Then also a beet-sugar factory operates seasonally only; the average length of the operating season is only about 100 days, and the earnings must be made during this short period. But at that some progress is being made, and at least one concentrating plant is under construction and several others under consideration and more of the values will be recovered during the 1917 campaign than during the past.

However, in these instances a recovery of all the values in the liquors is aimed at, not the potash values only. This will be touched briefly below.

Approximately the disposition of the potash in the sugar beet crop grown in the United States at present is as follows:

Returned to Farms in Pulp.....	10.0%
Found in Molasses Produced.....	90.0

The potash found in molasses is distributed as follows:

To Alcohol Plants	10.0% plus
Used as Molasses Feeds	40.0 "
Desugarized	45.0 "

This leaves under control of the manufacturers only about 40.0% of the potash content of the beet which on the basis of a six million top crop amounts to between 6800 and 7500 tons of K_2O .

This quantity is now disposed of as follows:

Directly to the soil as factory sewage.....	20.0%
Concentrated to 50-55% dry substance and sold to fertilizer factories	5.0
Concentrated and calcined to a crude ash.....	5.0
Discharged into streams and representing the stock of values now lost	70.0

Thus far the subject has been considered from the angle of recovering the potash for the chemical industries or the potash and nitrogen as fertilizers only. That does not by any means exhaust the possibilities. Beet-sugar molasses and therefore the waste water contains a great number of substances which in themselves are valuable or may serve as the mother substance for valuable products. The possibilities can here be touched on only very briefly.

Even in the case of potash and nitrogen it appears from the experience of Europe that the general economy is served best by combining these into a more valuable product. From Germany it is reported that by the Bueb process of destructive distillation the waste liquor of molasses desugarizing processes operating by the strontium process, in that country, produce annually 5000 tons of potassium cyanide and 5000 tons of ammonium sulphate. Steffens waters can be similarly utilized and an United States patent has been granted for such a process.

The molasses waste liquors contain a whole series of organic acids valuable to industry which can be recovered.

The nitrogen of these waste liquors occurs in various forms, partly as a plant basis of which the principal is betain, which has found some application in medicine. A large part of the nitrogen content exists in the form of amido acids. These it has been shown by Effront can, by suitable fermentation processes, be split into ammonia and a mixture of volatile fatty acids, acetic, propionic, butyric. Recent investigations in this country indicate that a mixture of the high boiling point Ketones valuable in cellulose technology, can be prepared from this liquor.

Ehrlich insists that the amido compounds present in considerable quantities in beet molasses waste liquors are the mother substance of fusel oil, more particularly amyl alcohol, and suggests extracting these compounds and utilizing them to increase the fusel oil production. This indicates only a few of the possibilities. While it is not claimed that beet molasses may yet prove another coal-tar, chemically it may be almost as interesting.

But little has been done in developing the waste liquors values in this country. The reasons are various. Not the least lies in the fact that sugar is a sort of national and international political football. Between duties, bounties, premiums, special international agreements as the Brussels Convention, and competition with the

tropics, the beet sugar industry in the United has never felt sufficiently safe to venture in new directions.

At the outbreak of the present war the outlook was particularly dark. The tariff had been lowered, and a duty free sugar clause enacted to go into effect May 1st, 1916. Fortunately, this latter clause was repealed before going into effect.

What the development of the future may be will depend more upon legislation following cessation of hostilities rather than present high prices and in this respect the beet-sugar industry is not differently situated than most other chemical industries in this country.

THE POTASH INDUSTRY OF CANADA

By E. B. BIGGAR, OF TORONTO, CANADA

Read at the Buffalo Meeting, June 22, 1917

The chemist of to-day who thinks of the production of potash in terms of the output of Stassfurt will be surprised to learn that at the middle of the last century between two-thirds and three-fourths of the world's product of potash came from Canada. Regarding this product as a Canadian industry it will be equally surprising to learn that for many years the export of pot-ash and pearl-ash ranked next to lumber in the shipment of forest products to other countries. In the fifties the export of potash and pearl ash from Upper and Lower Canada for several years exceeded a million dollars in value per year and a million dollars was a big sum to the Canadians of those days. It was very important to the individual settler in the first half of the last century, because it was the one product of all his varied labors that could be depended on for ready money. It was paid for in cash whereas most of his other earnings and crops were traded for groceries, dry goods and implements. His wool went to the custom woolen mill and came back in cloth or in roll cards for the settler's wife to spin; the wheat went to the grist mill and came back largely as flour and feed, and butter and home-made cheese came back in other groceries but potash always came back in real money.

In many parts of the country the manufacture of pot and pearl ash became a specialized industry carried on all the year round. Men were employed in going through the settlements, collecting the ashes saved by the farmer who burnt his timber, not more for the sake of clearing the land than for the sake of the money obtained from the sale of ashes. Many farmers had their own pots and converted their wood into potash, while every new settlement established an "ashery" in which both pot and pearl ash would be made, from ashes hauled in from neighboring clearings. In 1851 there were 237 asheries in Upper and Lower Canada (Ontario and Quebec). In 1871 there were 519; but by 1891 these had dwindled

to 128 for the whole of Canada, and now the industry on this plan is almost extinct. However, during the last few years up to the outbreak of the war the exports of potash from Canada averaged about 500 barrels per year, valued at nearly \$25,000, or \$50 per barrel. While during the last century Canada was the world's chief producer of potash she has now become an importer, the imports before the war averaging about 250,000 pounds, valued at about \$9,000. During the first half of the last century Great Britain was the world's chief market for potash, and the pre-eminence of Canada in this industry is indicated by the fact that in 1831, for example, Great Britain imported potash and pearl ash to the amount of 228,757 cwt. of which 169,891 cwt. came from British America; 15,835 cwt. from the United States, and the balance from Russia and Poland.

Most of this output was exported direct to England, the shipments by the St. Lawrence often amounting to more than a million dollars a year. Considerable quantities went out from Upper Canada by way of Buffalo, and frequent schooner loads came down the Grand River every season for delivery here to New York and New England ports. Potash entered England free from Canada, but until free trade was adopted there was a duty on American potash of six shillings per cwt. The price in England in the thirties was about £1/5/6 for pearl ash, and £1/4/6 for potash.

A Canadian work of reference, published in 1863 and edited by Prof. Hind, the geologist, and T. C. Keefer, the well known civil engineer, described the process of manufacture in Canada as follows: "The produce of the forest of most importance next to lumber has always been pot and pearl ashes. Potashes are made from the crude ashes by dissolving the soluble portion of the ashes with water, evaporating to dryness and fusing at a red heat into a compact mass, which although gray on the outside is pink within. Pearl ash is made by calcining potashes upon a reverberatory hearth until the carbon and much of the sulphur are dissipated. Water is then added and a lye formed which, when evaporated to dryness yields the pearl ash of commerce. Canadian potashes contain on an average 60 per cent. of carbonate of potassa. Pearl ash contains generally about 50 per cent of caustic potassa."

In the fifties the cost of manufacturing was estimated at \$10 per barrel when the selling price in Montreal was \$40, and, therefore, the manufacture of potash was strongly urged as an industry whose

profits were certain and permanent. One advocate stated the case thus: "No one item of our available exports is of higher importance than potashes and pearl ashes. In a country where it is necessary that vast tracts of wild land should be cleared,—land covered with a heavy growth of timber, useless in the main for other purposes than the manufacture of ashes,—this needs only to be looked at to discover its utility."

To-day the forests of Ontario are worth for other industries twenty to thirty times the value of their potash and Canadian lumbermen will learn with vexation that in the tract referred to,—that is, the region lying between London and Detroit,—the timber spoken of as worthless for any use other than potash, comprised birch, beech, oak, pine, maple, elm, cherry, hickory, ironwood, black walnut and many other woods which are now rare and costly.

With the clearing of the forests of Eastern Canada the potash industry declined, and this decline was hastened by the opening of the great deposits of Stassfurt, Germany. But since the war has cut off the German supply, and since Great Britain, the United States, and Canada and the other British Dominions seem to have determined that they shall be self-dependent as to such products, the present problem is to discover new sources of potash and nitrates,—both essential in the field of agriculture, as well as in chemistry. While it is true that in Canada and the United States there has been throughout the last hundred years an enormous waste of material in almost every industry, and none of greater enormity than in wood, yet all that can now be saved of the remnants of our forests will never restore the potash industry on the old basis. It will be interesting to note that the Town of New Toronto is now installing under the supervision of its engineers, Messrs. James, London & Hertzberg, a system of incineration for the treatment of garbage, by which potash is recovered to the value of \$7 to \$10 per ton. Thirty of these were installed at the military camps in Ontario and I understand they have been adopted in the United States Army camps where a thousand are now in use. Such endeavors to utilize the waste of cities should be encouraged, but, at best, they can only yield a small fraction of the potash required.

There is still, however, a source of potash in the feldspar rocks of America, vaster than has ever been exploited from wood, and without doubt chemists will sooner or later solve the problem of profitably extracting it. There are millions of tons of feldspar rock

in Canada and in some sections the potash contents run from 10 to 14 per cent.

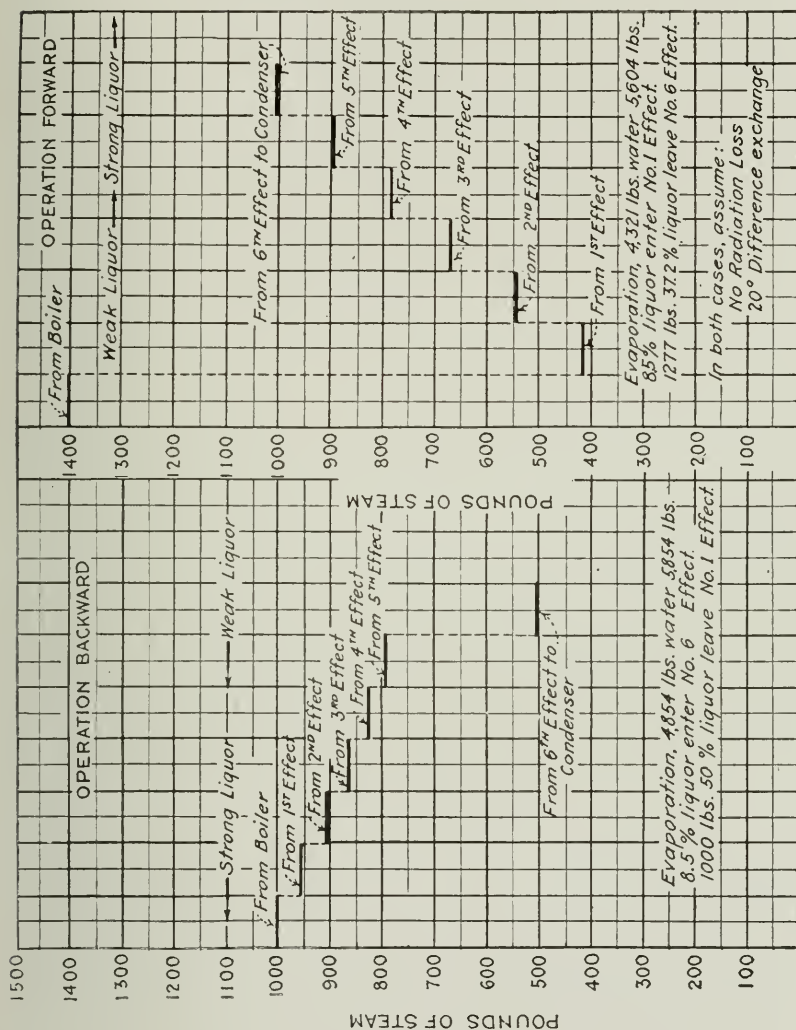
The cost of extracting the potash must be reduced by using other elements of the rock as by-products, and aluminium compounds, porcelain and Portland cement can do this in some districts. The making of potash as a by-product of the cement industry is now much talked of in Canada, but the claims made for the processes have not yet been demonstrated on a commercial scale; and, in any case, the output in this class is necessarily measured by the market obtainable for the cement.

Generally speaking, the areas of feldspar rock in the northern half of this continent yield a porcelain that is whiter and freer from iron, and for this reason large quantities of Canadian feldspar are shipped to the United States, ranging from 11,000 to 18,000 tons per year,—to be used in the pottery and porcelain industries, and for the manufacture of artificial teeth, etc., and there would seem to be room for further development of such industries and for aluminium in both countries in combination with potash production. When the nickel areas of Sudbury were opened up, the peculiar combinations of the ore presented a knotty problem to be worked out, but patience, skill and money solved every difficulty, with the result that to-day the Sudbury district now supplies 80 per cent of the nickel output of the world. There is every reason why all obstacles will be overcome likewise in the production of potash, and if so, the primacy in the manufacture of this most essential material will be restored to America.

DISCUSSION

Mr. HUGH K. MOORE: Mr. Chairman, I made a few notes on this and it seems that for many of the processes described cheap evaporation is one of the most important conditions necessary for the success of the processes. If you figure out the interest on the investment and the amount of yield in multiple effect evaporators,—it oftentimes does not pay to have over three effects, sometimes four effects, under rare circumstances five effects. The reason for this is that you start with a cold liquor and most of the input of the steam is used in the first effect in heating the liquor up to the boiling temperature. So in a calculation that I made on some evaporators once I figured that an input of steam on a multiple

effect system—I think it was ten effect—would be 33,000 pounds, but for the first effect you would only get 3,000 pounds of steam for an input of 33,000 pounds of steam, but as you go on from



effect to effect this liquor which has been heated gives up its heat generating steam, so that the greater part of the heat goes off through the condenser in the last effect. This inefficiency of the first effect

is what limits the number of effects which you can put into an evaporator. The increased efficiency does not compensate for the interest on investment.

When you deal with inorganic salts there is another method of evaporation by which practically there is no limit to the number of effects that you can use. You can get a reverse curve. In other words, instead of getting the maximum evaporation in the last effect and having all your heat going up through your condenser, you can get your maximum evaporation in the first effect with a slightly sliding line towards the last effect. In other words, in ordinary multiple effect evaporation you have a step up effect in the amount of steam liberated from each evaporator, but if you put your liquor into the last effect and pump it successively forward from one to another and put your steam into the first effect, then you flatten out this step effect curve and get nearly the same amount of evaporation in each effect. I do not believe there is any limit to the amount of effects you could use.

Of course, this kind of evaporation cannot be used on such things as cane sugar where you get invert sugar, because your final product comes off at very high temperatures; neither can it be used in glues or in any such things. But, based on experience of using sulphite liquors, we are already designing an evaporator of ten effects to concentrate digester liquor simply for its fuel value. Now, sulphite digester liquor contains about 6000 B.T.U. per lb. of solid matter. Figured on the price of Birdseye Mill at Berlin it would be only \$1.75 per ton. Nevertheless the figures based upon the work which we have done show that that liquor can be evaporated and burned for fuel with a possible yield of dividends after paying all expenses in fuel value of from 75% to 80% of the cost of the plant by running the operation backwards where it would be absolutely impossible and uneconomical to do it frontwards in the ordinary mill, so it seems to me that in this beet-sugar industry where you have only 4% and the salt is an inorganic salt which is not going to change, that the backward evaporation would solve that problem, especially where you have high fuel values, and the high price of potash. With the additional saving of the nitrogen content this could be accomplished in the above way and eliminate to a large degree the cost of evaporation. It might be worthy of consideration and considerable money might be spent in experimentation—in fact, we had already started on it when the Govern-

ment interfered with our work, taking our chemists for one thing and another.

What I am now going to say will seem at first as if one were trying to lift himself by his boot straps, but it is not so and is mathematically correct. For instance, the steam going to the condenser contains a very high per cent of the total heat which is put into the evaporator. Assuming under a vacuum that it contains 1100 B.T.U. most of which is latent heat, if you had electric power so that you could compress that steam, raising it to a high potential of temperature, you are only adding about 100 B.T.U. to it, but you are recovering 1000 B.T.U. plus the 100 B.T.U. which you have added in compression, and that steam can be put right into the first effect so that the only heat then that you lose is what you lose by radiation and what goes out in your drip liquor. Mathematically it is a sound proposition. Practically we do not know what difficulties are going to come up in the compression as we have not completed our experiments and do not know if we can get over the mechanical difficulties, but from what experiments we have made, it looks as if a large portion of this steam can be put into a positive blower and compressed say to somewhere near atmospheric pressure, and then putting it into a reciprocating pump and compressing it up so that you get your temperatures required in the first effect, then you get the whole latent heat of your evaporation into your first effect and could cut down your coal bills tremendously. As I say, we have not gone far enough to give any definite results on this, but I think it is a subject the possibilities of which chemical engineers do not realize, and if they will go into the mathematics of it they will see they are not trying perpetual motion. Of course, if you tried to compress that with steam you could not do it, because a steam engine would use up more than the heat which you would get by compression, but if you had electric power to furnish the power of compression then you get the most of the heat for your compression, and all the heat practically that goes out is in the drip, and in the final product which comes out in the last effect—which by the way is at a high temperature—but very small in amount, and what experiments we have made seem to show that this will in a short time be worked out on a practical basis.

There is another thing I wish to mention here, that is the action of the phosphide of soda on the silicates. Some years ago I was interested particularly in cheap production of ethane and

in making ethylene. I would use phosphoric acid at a temperature of about 250 degrees C. I found that it would eat right through glass or any of these things we used in the laboratory in the course of an hour. I even used fused quartz vessels and found phosphoric acid at this concentration would actually eat through these fused quartz vessels, but not so rapidly as in the compounds that contained potash and soda. The phosphoric acid, if you consider simply the potash from the fertilizer standard, can be made very, very cheaply. It is quite a problem in some mills to dispose of their chlorine. The chlorine can be made and you get muriatic acid from your electrolytic salts by combining the chlorine with the hydrogen. Your muriatic acid can be made cheaper than it can be made by using salt and sulphuric acid. Now if you treat ordinary phosphate rock with hydrochloric acid, you get a solution of calcium chloride and phosphoric acid which acts just the same as phosphoric acid, and this has a very marked action on the silicate rocks, but with the advantage that it has a selective action at the comparatively low temperature of 200 degrees C., dissolving out potash and soda, leaving to a large extent the silica, and this phosphoric acid is not a waste then because the phosphates are as necessary to the fertilizer industry as the potash, and the final product contains phosphate of potash. I think this is a line of investigation which might be attempted and which might prove very profitable.

Mr. GARLAND E. LEWIS: I do not happen to be a member of your Society, so that I will take up but just a moment of your time. I came all the way from Nebraska because I am interested in the subject of the morning and have enjoyed these papers very much, especially Mr. Meade's. I noted his explanation there of the occurrence of potash salts in the alkali lakes of Nebraska, and, by the way, this same opinion has been offered by the State Geologist of Nebraska; however, there is considerable difference of opinion on the point, and I think a proper investigation may prove the theory to be erroneous. The fact that those lakes or a part of them are strongly alkaline, particularly in potash, while lakes of a similar situation and evidently equally as susceptible to drainage from a burnt area have no appreciable potash content would seem to throw cold water on this theory. There have been no extensive borings whatever in the State to my knowledge. They have simply been utilizing the alkali potash water where it is found and it does not seem unreasonable at least to suppose that there may be an underground potash supply

from which these lakes are fed and which would account for the fact that a part of these lakes are very good paying lakes in potash content while lakes of a similarly favorable situation have no appreciable potash whatever. As I say, I think it is not unreasonable that borings and investigations in these regions may uncover an underground source of this potash supply.

There has been one other source which has not been mentioned this morning which I am interested in just now, and that is the alunite or the crude potassium aluminium sulphate of some of our western states, and I am going to spend the summer investigating one of those fields. The same problems, of course, present themselves up there as in some of the other sources here, namely, that we have the problem of getting rid of alum while the potash is probably more marketable. If we can find men of the East who are interested in the aluminium side or can utilize that side of the product I think it is not unlikely that the alunite deposits of some of our Western states may prove amply profitable as a source of potash.

Mr. LUDWIG A. THIELE: In considering all these papers of this morning, it seems to me, that while we have arrived at a certain production of potash in this country, it is not of such consequence as to warrant a great outlay for the future. These potash deposits are too low and the cost of production too high and by-products are not available. If you stop to think that the German potash industry obtains enormous amounts of by-products, such as bromine, chlorine, magnesium chloride and sulphate, their production is far in advance of the methods advocated right now. Really, my candid opinion is, that we should try to find better resources for potash in this country. If we would devote more of our time and money exploring this country, possibly by drilling in Arizona and the Western sections where we might be able to find rich deposits of potash salts, this would solve the proposition absolutely; but to find it out of cement mills, the beet sugar industry and so on, is a makeshift only for the present and cannot last.

Mr. WILLIAM M. BARR: In connection with Mr. Lewis' suggestion on the theory of a continuous underground supply of potash in the Nebraska fields, I may say that in connection with the study of water supply of the district west of the Mississippi River and particularly Nebraska, I have made a good many borings, both of deep and shallow wells, and I have never found anything that would lead me

to believe that such a theory would ever prove to be correct. The deposits there must certainly be more or less localized, as has been the prevailing opinion among chemists.

I was very much interested in Mr. Meade's description of the Cottrell process for the precipitation of the cement dust in the obtaining of potash and particularly in the use of feldspar at the Riverside plant. I would like to ask him in this connection if he considers that it would be possible to substitute a leucite bearing rock. My understanding is that the feldspars used run in the neighborhood of 8 to 10 per cent K_2O . We have leucite bearing rocks which carry at least 11 per cent and some of them higher, and I have been wondering if such a material might be substituted for feldspar with profit to the potash content and without detriment to the cement product.

Mr. R. K. MEADE: You can substitute almost any substance high in silica and alumina for at least a certain part of the clay element in cement. With the exception of the Lehigh Valley District in Pennsylvania, all of the cement in the country is made from limestone and either clay, blast furnace slag or shale. Any material can be substituted for the clay or shale which can be ground easily and that will give a mixture in which approximately the percentage of silica is about twice that of the iron and alumina together and in which the proportion of the iron is less than one-third of the alumina.

Mr. WILLIAM M. BARR: That is the question I had in mind, Mr. Meade, was whether the leucite rock should be used without reducing the aluminium content too far.

Mr. R. K. MEADE: I do not remember the exact composition of leucite but I believe it is quite high in alumina. As a matter of fact, a great many limestones used for the manufacture of cement are too high in silica, and in such cases I believe the cement could be materially improved by adding thereto some material high in alumina, so that I have no doubt that there are lots of places where leucite could be used to actual advantage.

Mr. WILLIAM M. BARR: Well then of course the commercial considerations would enter in.

Mr. R. K. MEADE: I think probably 50 per cent of the plants in the country could use some leucite to advantage to bring up the alumina in their cements.

Mr. MAXIMILIAN TOCH: Mr. Chairman, I would like to know whether anybody has any knowledge as to what England and

France have been doing with reference to potash since the beginning of the war. I would also like to know whether anybody has any definite knowledge other than perhaps hearsay as to the truth of the statement that Russia has been trading with Germany throughout the war, getting large quantities of potash in return for other materials. I have heard this several times, and the fact that the Russian wheat crops and other crops have not been a failure would point to the fact that they had been trading with each other in spite of the fact that they are at war. But it would be of interest to know how England and France have been getting along, and whether any progress has been made in the manufacture of potash in those two countries.

The last paper has been of great interest, but there is one point I have learned since the paper has been read with reference to the garbage incinerator that is being erected near Toronto. I understand that that incinerator is at a large military camp and I have asked, but the gentleman in question did not know, the exact facts as to whether the grease at this military camp is to be extracted from the garbage before it is to be burned. It looks to me as though in these days incinerating fresh garbage is almost criminal, because the garbage contains such a very large amount of grease. In the City of New York you are probably aware there are over 1200 tons per day of poor garbage collected. When I say "poor garbage" I mean nothing from the wealthier quarters or from the hotel districts is regarded as garbage. All the hotel garbage is sold for the feeding of pigs in and around Jersey, because it is very rich material, but the other garbage, amounting to a minimum of 1200 tons per day, is extracted first, the grease taken out, and the remainder is sold as a fertilizer base. Before the war this fertilizer base which is known commercially as tankage, was sold on its nitrogen and potash content. Now, of course, it is of very great value simply on account of its potash content, but it was very difficult to sell it before the war because it was so low in nitrogen. It may be of interest to the Institute to know that while I know practically little or nothing on this subject and very seldom take anything outside of my own line, I was consulted on this fertilizer base because they had a mountain of it which ran so low in nitrogen it could not be sold and it had to be removed and there was no way of adding any nitrate salt to it, because that would have made it entirely too expensive, so that the thought struck me—and six months time was given to this investi-

gation—of planting soya beans on this tankage, which would extract the nitrogen from the air and increase the nitrogen content. And it so happened. The nitrogen content went up to the required amount and the green soya bean growth was turned under at the proper time and this amount of fertilizer was sold.

Mr. H. O. CHUTE: Mr. President, Mr. Meade's paper has so well reviewed the subject of the potash manufacture that there is very little left for me to say on a subject that I thought might perhaps be of interest, and that is the manufacture of potash in the West. I may, however, supplement his remarks to some extent and mention some of the developments that he has not touched on.

The Hawaiian Islands have been intensively cultivated for sugar for a number of years, using a considerable quantity of fertilizer, including Stassfurt salts. The molasses produced from the cane contains from $1\frac{1}{2}$ to 2 per cent of potash as K_2O , and before the war some of the plantations had dumped the molasses into the irrigation water, which being spread on the fields, probably retained the nitrogen, and potash was probably absorbed by the natural zeolites and held there for a future crop. At the present time about 250 tons of molasses daily come from the Hawaiian Islands and are distilled for alcohol around San Francisco. The largest plant treating 150 tons of molasses daily is saving the potash. The molasses is fermented with a dilution of from four to seven times its amount of water and probably the amount of potash in the slop is not very great. This is evaporated or was evaporated a year ago in Porion evaporators such as those described by Mr. Moore yesterday as being used in sulphate mills formerly; that is, flat furnaces containing disks revolving on a shaft. These, of course, only give a single effect evaporation, but at the present time it pays, and a large amount of potash salts are recovered. The slop is evaporated to a sludge in the rear pans with the stirrers and then thrown into the forward compartment, where it burns in the furnace down to a char. This is brought out and sometimes sold direct, perhaps in other cases treated for chloride of potassium. There is one instance in the utilization of beet sugar molasses residue in the form of Steffens waste as described in a previous paper of which our member Mr. Edgar Baruch is in charge, who has written a letter to the Secretary, who gave it to me, but the letter says little about what he is doing. He merely mentions beet sugar waste.*

* See letter on page 101.

By the processes described in Dr. Zitkowski's paper, a hastily erected plant last year was constructed by which this dilute solution of Steffens water was sprinkled down a tower up which the fire gases were ascending and the solution was thus evaporated. A rather large amount of loss by K_2O by volatilization took place rather unexpectedly, and the lime salts in the Steffens water were also troublesome in forming scale. I think that this year a much improved apparatus has been put up.

The manufacture of potash from kelp has been touched on rather extensively by Mr. Meade in his paper, but while the kelp is undoubtedly in smaller quantities than was originally supposed, yet the Pacific Ocean is rather large and though it is only in favored spots that the kelp grows, there is quite a considerable shore line along the United States and Canada and Mexico that is as yet untouched. The kelp nearest the plants, of course, disappears rather rapidly, so that they have to go farther away. The Diamond Match Company has a rather large plant seemingly in rather successful operation at Los Angeles harbor, San Pedro, and the other plants have been mentioned.

I might state that the plant of the American Products Company that was presumably making knife handles has been reorganized as a potash producing plant again and I think is producing on a fairly commercial scale now at rather profitable prices, having suffered from some early contracts where they contracted for potash at much too low a price. The developments at San Diego have been mentioned. The Swift plant could best be described by Mr. Richardson and I hope he will give us some information on the subject. And the Hercules Powder Company's plant down at Chula or San Diego Bay is worthy perhaps of more mention than has been given.

The idea of utilizing the kelp by first fermenting it, is perhaps novel, and has the great advantage of destroying the colloid form. This colloid has as its special mission in life the retention of potash against a world of salt water, but after fermentation you have merely a crystalline solution of potash and other salts. After fermentation as described in the presence of calcium carbonate, sodium sulphate is added forming acetate of soda, and the precipitation of the residual lime as calcium sulphate, and lately another step has been added, the addition of carbonate of soda and the elimination of sulphate of lime, which is troublesome in later evaporation. This fermented solution is decanted or separated in a Dorr separator or

thickener. The separated clear liquid is not filtered but the sludge is filtered in Kelly filter presses and in Oliver rotary filters with very successful results, particularly with the Oliver rotary filter.

The presscake coming off is very hard and very satisfactory and the solution is quite clear and is evaporated in two sets of quadruple effect evaporators of large capacity, of the Kiestner style with tubes about 22 feet long. The evaporators are six feet in diameter, and evaporate many hundred thousand gallons per day, and in their quadruple effect the evaporation is necessarily quite cheap. Were it not for a previous fermentation, the elimination of the water by multiple effect would be impossible, and this is the big problem in kelp utilization, the elimination of the water which in the best case is at least 85 per cent of the volume of the kelp as received. Unfortunately, in their fermentation some water has to be added. At the present time there is no pure culture of yeast or bacteria or anything used except the natural bacteria which accompanies the kelp, and I do not think that they are using the process which we call in the alcohol business yeasting back, or as our sanitary friends call it, using activated sludge; that is, transferring active bacteria to an incoming solution that may be later on fermented, but it is merely the bacteria which accompany the kelp which suffices for fermentation.

When the liquid is evaporated down to the crystallizing point, it is run into ordinary salting out evaporators which are worked at the atmospheric pressure under single effect, and salt out the sodium chloride which at first is very pure, but the later portions are very impure and are sent through a series of centrifugal separators where by washing with various waters it is purified from the potash and the potash is recovered again. After the salt is precipitated as far as possible or desirable, the solution is transferred over to what they call the cold side. These are crystallizers built with salting-out boxes at the bottom just like the ordinary salt evaporator, but they are artificially cooled with a brine solution. Here the potassium chloride crystallizes out and falls to the bottom and the sides of the evaporators are scraped, keeping them clean. The residual liquor contains almost anhydrous sodium acetate and I understand they have to add water before it will crystallize out with its natural water of crystallization. This sodium acetate thus crystallized out from the residual liquor is dried, rendered anhydrous, and the residual liquor is not, as yet, further treated for any other products. The anhydrous

sodium acetate is ground and put on a conveyor and sprinkled with the theoretical amount of sodium acid sulphate being of course the niter cake from the nitroglycerine plants, and this mixed powder runs into a horizontal tube with a screw conveyor in it, the tube being heated to a temperature by which double decomposition takes place, forming normal sodium sulphate and acetic acid. The acetic acid goes over to a catalizer which is used to convert the acetic acid into acetone. Those who are interested in that catalysis can look up Dr. Squibb's *Ephemeris* of about 1896. He worked the problem out very thoroughly.

The acetone, containing some acetic acid goes into some separators or evaporators and condensers by which the acetic acid is returned and the acetone is separately condensed as crude acetone, and then is distilled in the ordinary beer and column still of the American type, which was originally put up on the European continuous type, but the workmen being more familiar with the American type have converted it into the familiar style. But the acetone product is very pure and quite a little ketone oils are saved and the potash is sent out as potassium chloride and not as potassium sulphate, and of considerably over the standard 80 per cent.

I think that this represents a fairly good utilization of kelp and it is quite possible that even in normal times this plant may continue. The initial costs were very heavy, but having once put in the investment and as the capital is returned quickly under war prices, they need not consider capital investment, and the operation is not very expensive.

The Oregon lakes have been touched on. Analyses were given of the lime in the Summer Lake. I saw the Abert Lake, which is about 30 miles north of the last railroad in northeastern California, which is said to be similar to Summer Lake, but being 30 or 40 miles from the railroad the conditions are rather unfavorable so far as freight rates are concerned. Although they have potash in their waters, there seems to be some doubt as to how much. This I did not test.

I am reminded here by the present discussion of the deposits in Nebraska that on the side of this lake, the Salt Lake, there is a spring of what seems to be practically fresh water, with fish in it, coming up from an unknown depth and with a very strong flow of water, so that seemingly the salts that are found in those lakes do not come from underground sources. And I may say that 35 miles

further north there is what is known as Soda Lake in which there are immense beds of crystalline soda and on the shores of this lake pure spring water comes up in large quantities, so that the salts there are not derived from any deep springs, but must come from surface water.

The cement work has already been described and touched on. It is to be observed that the California cement industry is rather a leader in the potash recovery problem and that one of our members is connected with each of those plants that are prominent in that line.

Of the Utah alunite deposits something has been said and I can say nothing further.

The bitterns of the ocean water have been treated for potash at two salt works around San Francisco Bay where about 500 tons of salt daily is made.

Of the bitterns of the Salt Lake I might say that roughly speaking the great Salt Lake contains about 22 per cent of salt and a half of one per cent of potash, estimated as K_2O . The salt works evaporate off the salt in the summer during the dry season and towards fall have a large amount of bitterns containing about 2 per cent of potash. This is the substance which is being utilized at two plants, one owned by the Diamond Match Company and the other by the Utah Chemical Company. I am sorry Dr. Wesson has left, because he could give us some pretty good information about the Utah Chemical Company, and I am rather reticent in saying very much about it while he is not here, but it is merely a question of evaporating down this bitterns to crystallize out a rather crude potassium salt which is suitable for fertilizers, and that is the only thing that is desired, so that no further work is done at the present time, particularly at the Utah Salt Company, than to evaporate down the bitterns and eliminate a large quantity of salt in the salt boxes while the water is hot, and when they cool down a very large proportion of potash salts come out not containing much more than 15 to 20 per cent of K_2O . But this is very satisfactory at the present time as fertilizer.

As the Nebraska deposits have been touched on, I cannot say anything more, because we have men here who know a great deal more about it than I do, but I want to refer to Searles Lake, and in this connection we have a visitor here with us, Mr. Walter L. Jordan, who has slept out in the desert on the shores of Searles Lake for a long time and perhaps he can say a few words to us as to the actual

conditions out there which would be very interesting. By the way, the Solvay Process Company, I understand, are doing very well out there now, having recently erected a plant under the supervision of our member, Mr. Shattuck, and they are reported to be shipping large quantities of potash from that locality.

The Owens Lake belongs to the same system as the Searles Lake. The Owens Lake is fed by the Owens River and at one time discharged into Searles Lake, but for ages the connection has been broken and while Searles Lake is dry, the Owens Lake contained in 1913, 11 per cent solids of which 2.8 per cent is K and about 36 per cent is sodium carbonate and bicarbonate which is crystallized out as trona. Two companies on the lake have made a start towards recovering the potash from the bitterns or residue from the trona crystallizations. There have been some attempts to obtain potash by burning the unlimited quantities of sage brush in Arizona, and the Government has conducted experiments on destructive distillation of it to produce tar or oils suitable for ore flotation. Perhaps the combination of the destructive distillation for flotation oils and the recovery of potash from the residue may be profitable.

In conclusion I may say that it can be seen that the West is doing its share of chemical engineering on this particular problem.

Mr. EDGAR BARUCH: (Communicated.) The Hercules Powder Company have an enormous plant at San Diego which cost about \$2,500,000 and they are the only people on the coast who to my knowledge are refining their potash products.

Swift & Company, also located at San Diego, merely cut and dry their kelp. The Long Beach and San Pedro plants carry the process further by making a charred ash, which runs from 30 to 40 per cent potash as K_2O , but do not attempt to purify or concentrate the potash salts. Dr. J. W. Turrentine of the U. S. Bureau of Soils is spending \$175,000 of the Government's money on a new plant near Santa Barbara with the idea of attempting to find valuable by-products from the kelp, but which as near as we can determine will merely duplicate much of the work already tried by the old promotion and pioneer plants. There is much talk about still other plants being constructed all along the coast as far north as Seattle.

To my mind, in spite of many predictions to the contrary, it appears that the shortage in kelp, already noticed and felt, will soon prevent further expansion of the industry. Moreover, the costs of production are increasing so rapidly because of the necessity of

going to distant beds for the kelp, that it is difficult to figure how the industry could survive pre-war prices for potash.

It may interest you to know that we are attempting to develop other sources of potash in this State, and the whole subject can be summarized briefly, about as follows:

- (1) Lake Beds and Deposits.
 - Searles Lake.
 - American Trona Corporation.
 - Solvay Company.
 - Nevada Deposits.
 - Hercules Powder Co.
- (2) Kelp.
 - Hercules Powder Co.
 - Swift & Co.
 - American Products Co.
 - American Potash Co.
 - California Potash Co.
 - U. S. Bureau of Soils.
- (3) Cement Dust.
 - Riverside Portland Cement Co. They also refine for K_2SO_4 .
 - California Portland Cement Co.
- (4) Beet Sugar Waste Waters.
 - Oxnard, Huntington Beach, and Los Alamitos.
 - Chino, and Spreckles in charge of Edgar Baruch, Los Angeles.
- (5) Sea and Lake Bittern Waters. (Still in developmental stage.)
 - At Long Beach the bitterns from the salt works are used for the extraction of magnesia and the final liquors saved for potash.
 - At Owens Lake after removal of soda salts bittern waters contain valuable quantities of potash.

Mr. WALTER L. JORDAN: I do not think I have anything important to add. It has been about three years since I have been out at Searles Lake. I have just thought over the analysis of the brine as I remember it. Mr. Meade gave 33 or 34 per cent of total salts in the brine. Those consist of about 16 per cent sodium chloride, 6 per cent sodium sulphate, 4 per cent sodium carbonate, one per cent

sodium bicarbonate, 3 per cent borax, and 4 per cent potassium chloride, using the conventional combinations, the ratio of potash to soda salts being about one to eight.

It seems to me that the problem at Searles Lake should have been attacked from a physical-chemical standpoint. The brine contains a mixture of ions whose equilibria is unknown. Solubilities of sodium and potassium chlorides and sulphates are known, but the separation from Searles Lake brine is complicated by the presence of borates. If this problem had been taken up several years ago in a manner similar to Vant Hoff's work on the Stassfurt salts, it would have very likely saved a great deal of time and money.

SOME MACHINERY EMPLOYED IN THE MANUFACTURE OF GLUE

By ARTHUR LOWENSTEIN

Read at the Buffalo Meeting, June 20, 1917

In view of the fact that most of the improvements in the glue industry—at least so far as pertain to distinctive improvements in equipment used in the manufacture of glue in this country—have taken place largely in that portion of the industry devoted to the chilling, cutting, and spreading of glue, that which follows in this paper will be limited to this phase of the subject. In other words, it is not the purpose of the writer to treat on the preparing of raw glue stocks, the chemical treatment of such stocks and their subsequent cooking and evaporation, but rather on the product after it has left the evaporator.

The progress made in the glue industry in this country has been very gradual, and most glue manufacturers have been exceedingly conservative in adopting new equipment.

The old method of handling glue after it leaves the evaporator (and this method is still in use to a considerable extent) consists in running the concentrated glue solution into wood, galvanized iron, or zinc pans or "coolers," (such material being used to avoid staining the jelly with rust), and chilling these pans by means of running water, or usually in a refrigerated room, after which the product is removed either by cutting or by dipping the pans in hot water. The cakes formed in this manner are then either run against wires or knives. The Clyde cutting machine when originally invented marked a distinct advance in the method of cutting glue. The Clyde machine is of the wire cutting type, made single or double, and is probably the most satisfactory machine of this type.

In some cases the chilled glue is chopped into blocks and then each block placed in a contrivance where, by the pressure of a lever, knives or wires descend on the cake of glue and cut the block into sheets.

Knife cutters will cut heavier jellies than the wire cutters, and this is desirable during the Summer period. One of the objections raised against the knife cutters is that they "do not separate tops and bottoms."

Glue jellies when cut too stiff show a roughened surface, the appearance of which is unfavorable when dried.

After having been chilled and cut by any of the methods cited, the glue is spread by hand on nets.

The old system of chilling glue requires a chilling room sufficiently large to store several days' production of glue in coolers. It has frequently been found desirable in designing a glue plant using this method to arrange the chill-room so that outside temperatures can be used when suitable. The jellies must not be kept too long in these coolers, as even at low temperatures molds develop and depreciate the quality of the glue.

The principal objections to these methods of chilling and cutting glue have been that they require considerable space for cooling room; an excessive amount of refrigeration where only a limited surface of glue is exposed to the refrigerated air, and as a result most of the heat has to be conducted to the air through the medium of the metal pans; that if the coolers or pans are made of galvanized iron they rust badly and have to be replaced; that they frequently leak, with consequent loss of product; that one has "tops" and "bottoms" which prevent uniformity of product or make it necessary to put these parts into a lower grade or into some other commercial form; and that the product has to be kept so long in the coolers that in warm weather, particularly humid weather in Summer, the quality of the glue is so affected by liquefying organisms that the glue maker has serious difficulty both in the cutting and drying of the glue; and finally, the labor in filling these pans and emptying them, cutting by the methods outlined, and finally spreading the product by hand on nets, is not only laborious but costly.

Because of these facts experiments have been carried on for years in the effort to secure mechanical or automatic devices of a continuous nature which would simplify the procedure and thus avoid so much loss and handling of the product. Various types of chilling rolls have been tried from time to time without success. The Cooper factory employed a chilling wheel years ago for this purpose, in which the wheel, chilled from within, picked up the

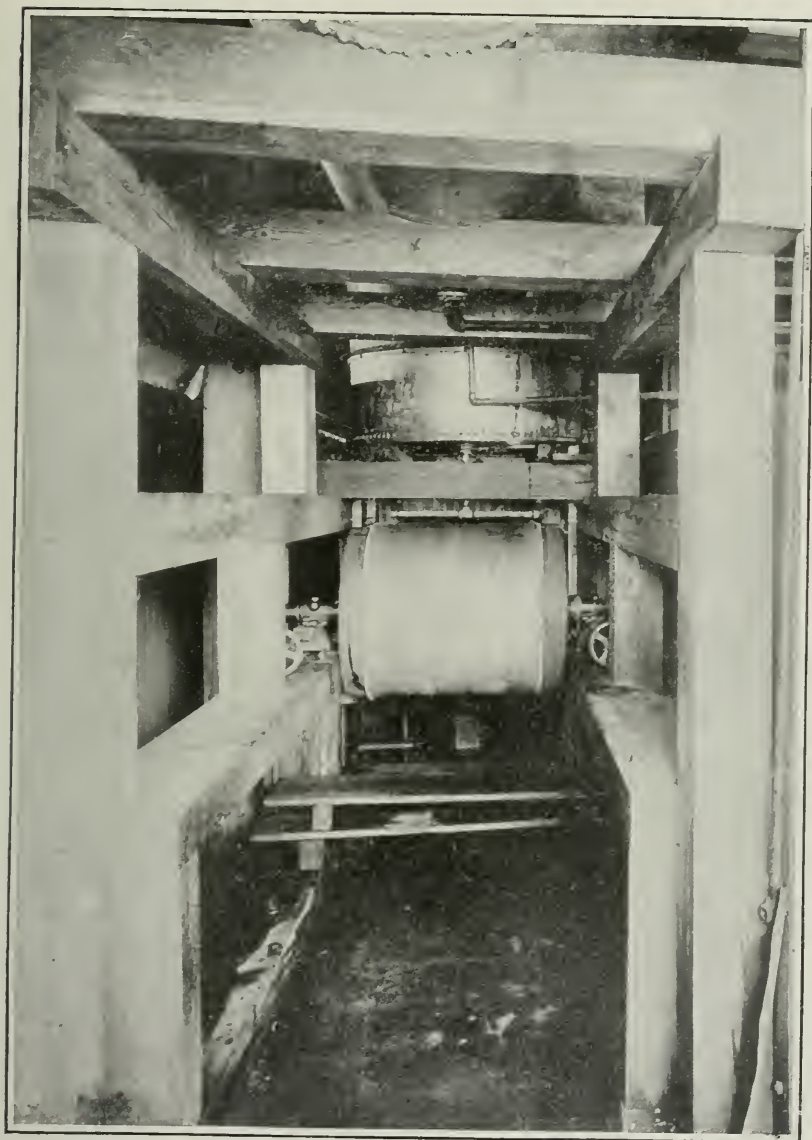


FIG. 1.—Feed Tank and Distributing Pipe Feeding the Glue Solution onto the Belt. (The large tank at the top is not part of the machine)

liquid and chilled it; but somehow or other the process did not turn out to be practical. The writer has been informed within the last few years that one of the large glue companies has perfected a similar process, or at least is employing it commercially, in which a large wheel is employed. It is his understanding that this wheel may be 14, 16, or 18 ft. in diameter, with cored and flanged rim, using brine circulation in the rim which is supplied and circulated through stuffing boxes in the ends of the shaft. It is his understanding that this wheel spreads a sheet 30 in. wide. The writer wrote to the President of the company employing this machine, and had hoped to be able to include a cut and a more detailed description of it in this paper. So far as he knows it is only used by this one company.

Some years ago when the Bureau of Chemistry of the United States Department of Agriculture started to investigate the gelatine industry with a view to decreasing the bacterial count of commercial gelatines and to prevent metallic contamination, some manufacturers found it necessary to adopt different methods of manufacture from the very beginning, in the selection of their raw materials and particularly in their method of handling the product from its inception until it reached the final stages. Inasmuch as gelatine is a particularly good culture medium for bacteria, it was found desirable to concentrate efforts on methods which would reduce the period of time after the gelatine left the evaporator until it was converted into sheets or other finished form. The object sought was to obtain a continuous method of chilling, cutting and spreading the product without having it come in contact with agencies carrying bacteria, such as employees' hands, etc. A method of this kind was worked out and later patented by Maurice Kind under United States Patent No. 1,046,307, issued in 1912. His method consisted in running the gelatine from the evaporators into a head tank located above a continuous belt, as shown in Fig. 1 (11,369). A general idea of the principles involved in connection with this machine can best be gathered, perhaps, by quoting some of the objects of this invention directly from the patent, and from photographs shown herewith. A more detailed description can be readily obtained by reference to the patent itself.

"An object of the invention is to provide an apparatus wherein gelatin or other products where heat is necessary for extraction, may be converted from a liquid state, into a semi-solid state, by

means of treatment with chilled air, and thereafter cut into the desired shapes for marketing purposes.

"A further object of the invention is to provide an apparatus of the above character with means for directing chilled air on to the upper surface of the semi-solid sheet, as it is formed and passes through a cooler on a conveyor.

"A further object of the invention is to provide a device of the above character with cutters for cutting the semi-solid sheets into strips.

"A further object of the invention is to provide an apparatus of the above character with a cutting means for cutting the strips into sections, together with a conveyor for receiving said sections which conveyor is so timed in its movements as to space the sections in trays carried by the conveyor."

To sum up, this machine consists of a device for chilling the product in a continuous sheet of the required thickness, spreading on an endless belt which passes through a refrigerating tunnel, and automatically cutting the gelatine into sheets of the desired size and spreading it automatically upon the usual screens employed for receiving it preparatory to drying.

This machine was perfected and was found to accomplish the desired purposes in the manufacture of gelatine. A number of glue makers learned of the use of this machine for gelatine, and about five years ago the first of these machines was installed for glue. It has been found well suited for this purpose, and capable of chilling, cutting and spreading any kind of glue which could be handled by the older methods previously outlined. As a result, a large number of both large and small glue manufacturers have adopted this machine. The manufacturers of this machine advise that it requires a floor space of about 85 ft. in length and 10 ft. in width for the installation of a single machine; that the power required to operate fan and belts is about 10 horse power; that it requires about 10 to 12 tons of refrigeration per machine, and that the capacity of each machine is about 4300 lb. of dry glue in a period of twenty hours, based on spreading the glue $\frac{1}{4}$ in. thick, and on a basis of glue fed to the machine containing 16 per cent solids. It is found in practice that the glue is spread on nets ready for drying, in not to exceed fifteen minutes from the time the glue leaves the evaporator. Their claims for the machine are that it eliminates all of the disadvantages ascribed previously in this paper to the old methods of handling.

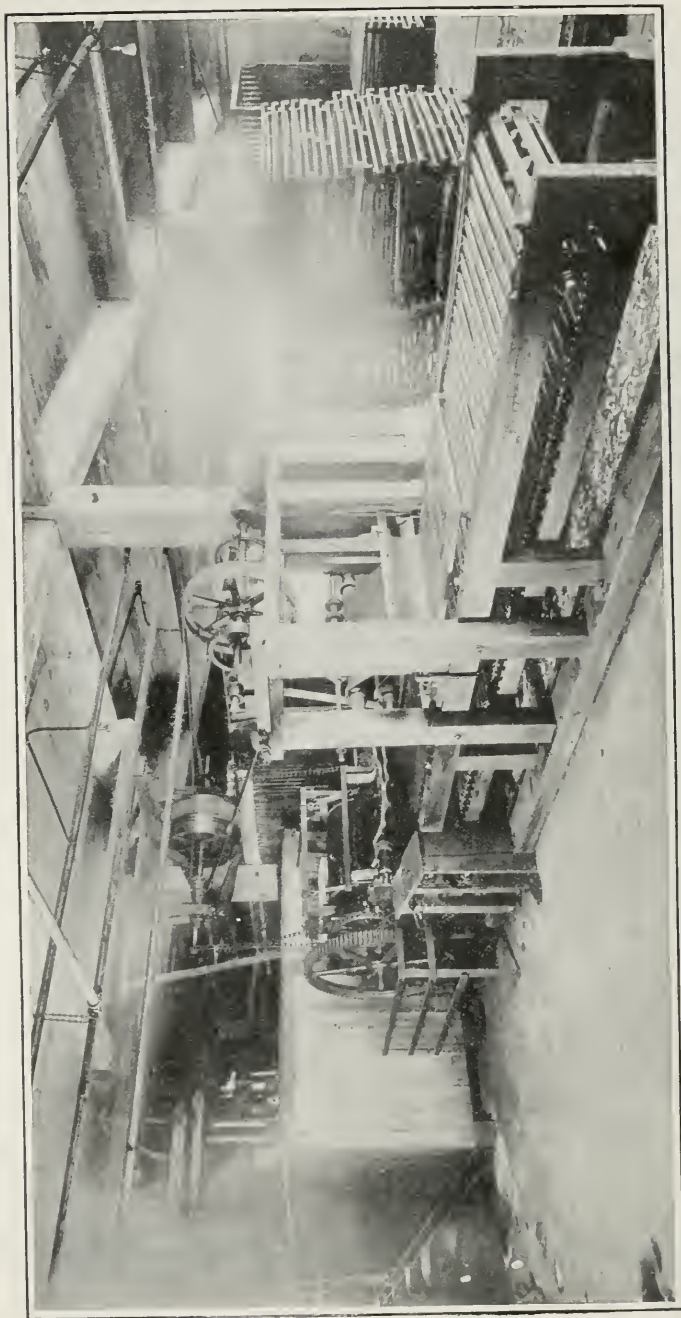


FIG. 2.—Chilling Roll and Spreading and Cutting Devices of Kind Machine

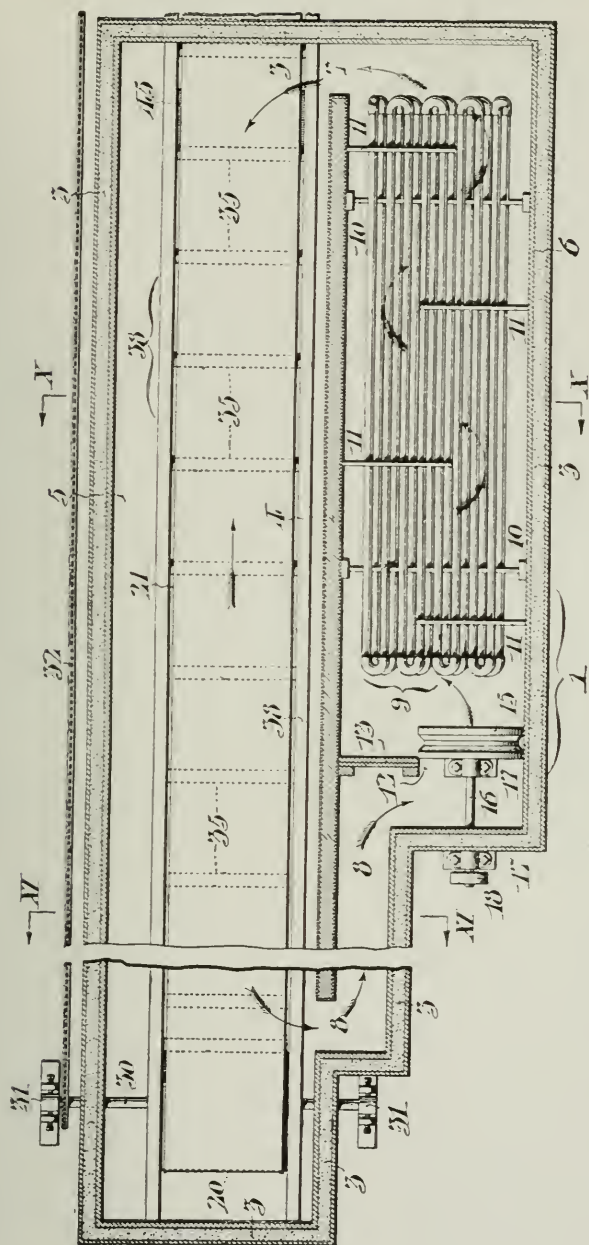


FIG. 3.—Plan of Cooling Compartment Showing Relative Position of Belt and Coils, and Direction of Travel of the Glue Spread on the Belt and of the Refrigerated Air

Fig. 1 is a photograph showing the feed tank and distributing pipe feeding the glue solution on to the belt.

Fig. 2 is a photograph showing the chilling box and the spreading and cutting devices of this machine.

Fig. 3 is a plan of the cooling compartment showing the relative position of the belt and coils, and the direction of travel of the glue spread on the belt and of the refrigerated air. (Fig. 9 of the Patent.)

DRYING OF GLUE

Glue has been and is still ordinarily dried in straight tunnels with longitudinal circulation of warm air. There is a great difference of opinion among the different operators as to the best length of glue tunnels, the size and kind of fan, the method of temperature regulation to be employed, whether a suction system or positive pressure system should be used, etc., but it is not the purpose of the writer to enter into a discussion of these points.

A number of other methods of drying glue have been attempted and some are being employed. Vacuum driers of one type or another have frequently been tried, but in most instances without meeting with commercial success. One company builds a drier with rotary air circulation, passing alternately over the coils and glue nets, which they recommend for glue drying.

In conclusion, the writer wishes to express his thanks to Mr. F. S. Williams; also to Mr. L. A. Kind for information relative to the Kind machine.

DISCUSSION

Mr. H. O. CHUTE: I would like to ask the author whether any attempts have been made to dry glue in a tunnel heated with partially saturated air, or, as they call it, moist air. About twenty years ago I was shown a lumber drying kiln in which it was said that they used moist air to dry lumber, and that has been introduced to a considerable extent. A few days ago I examined a kiln which is being introduced very largely for drying rubber, seemingly with considerable success, and its claimed advantages are that it keeps a constant moisture ratio in the atmosphere, regardless of the temperature, and I would like to ask whether moist air of any kind has been used in drying glue.

Mr. ARTHUR LOWENSTEIN: Mr. Chairman, in answering that question I would say that to my knowledge there has been no deliberate attempt to use moist air. There is always, of course, a certain amount of humidity in the large volume of air employed in drying glue in tunnels. It is usually desirable to have that air as dry as possible; some people have attempted to remove or reduce the amount of moisture in the air used for this purpose. The glue makers' troubles usually consist in an excessive humidity and his attempt in the drying tunnels is to get a skin formed on the surface of the glue to prevent it running through the nets, so I think the tendency is rather to prevent any excessive moisture.

Mr. HARRY O. CHUTE: That possibly explains why moist air should not be used in drying glue, for in drying lumber or drying rubber the attempt is to prevent a surface drying so that the moisture from the interior may continually come through to the surface.

THE MANUFACTURE OF LINSEED OIL

By **GLENN H. PICKARD**

Read at the Buffalo Meeting, June 20, 1917

Practically all of the flax seed or linseed crushed in America is handled in the open plate hydraulic press. Until recently a small proportion of the oil was won by the extraction of the seed with naphtha, but with the recent destruction by fire of the last plant operating on this principle, the process, so far as linseed oil is concerned, ceased to be in this country. The expeller is employed in a few mills, but the amount of oil produced by this means is a very small proportion of the whole.

The first step in the manufacture of linseed oil from flax seed is the cleaning of the raw material. The removal of the foreign matter in a consignment of seed is accomplished by specially designed flax screening machinery, which employs the usual method of passing the grain over screens of proper sizes which separate, as completely as possible, the foreign matter from the flax seed. A current of air removes the chaff. This procedure will reduce the percentage of impurities to an amount lying between 1 and 2 per cent. The screenings are generally run through a separator and the wheat, corn, oats, and possibly other grains are sold as such, while the wild buckwheat, pigeon grass, wild mustard, and other valuable weed seeds are sold to feed manufacturers.

The presence of oleaginous seed would deleteriously effect the quality of the linseed oil because the oils yielded by them are non-drying. The extent of the damage would, naturally, vary with the amount present. Non-oleaginous matter, particularly immature seeds and bits of the plants, impart a dark greenish color to the oil. The presence of much foreign matter will reduce the yield by absorption. It is economically possible to clean to such an extent that from but 1 to 2 per cent of impurities remain.

The cleaned seed is now crushed by passing it back and forth between rolls which are built in stacks of five. They are usually made of chilled steel and are 14 in. in diameter by 48 in. long.

The journal boxes are loose in vertical guides so that the weight of the other four is carried by the bottom roll. The seed passes between rolls four times and at each successive passage the pressure is increased by the weight of an additional one. The top, middle, and bottom rolls are driven by power applied by rope or belt drive as the case may be. The object of the crushing is to disintegrate the seed, thus breaking down the cell walls preparatory to expression of the oil. Consequently, subdivision to the greatest possible extent consistent with economy is the best practice. Generally

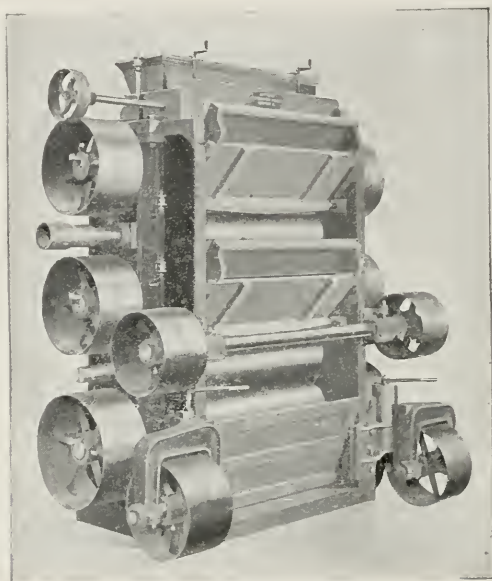


FIG. 1.—Crushing Rolls

all of the rolls travel at the same rate, so that there is no grinding or mulling action to assist in the disruption of the seed itself.

Stacks of rolls have been built in which the speed of each varied, thus producing a grinding action by slippage at point of contact. No data are available to show whether or not an increase in yield resulted.

Given a standard set of rolls the two important variables are the revolutions per minute and the rate at which the seed is fed. Practice in both varies. Obviously the more rapid the rate in both instances the poorer the grinding will be. Observations have

led to the conclusion that the crushing of about $10\frac{1}{2}$ bushels per hour at a roll speed of 150 revolutions per minute is the most economical practice on rolls 14 by 48 in.

In order that, when placed under pressure, the ground seed may more quickly, more easily and more completely give up the oil it contains, it is heated with or without the addition of moisture. This is accomplished in the heater or cooker, the unit of which is a cylindrical chamber with a steam jacket on the bottom and around the sides. These cookers vary in diameter from 42 to 84 in. Linseed oil mills are generally equipped with 72- or 84-in. cookers. The depth of the chamber is about 24 in. From two to four units, one above the other, are generally used. In each receptacle there is a sweep which lies very close to the bottom, in order that the meal may not lodge there and burn. The shaft to which these sweeps are attached is hollow. A finely perforated pipe is fastened to the back of the sweep and is connected to the opening in the shaft. Through this system steam may be admitted to the meal.

There are two practices followed, one in which the two-unit cooker is employed and steam is lead into the meal in the upper chamber. The amount of steam varies with the moisture content of the seed. The feed is so regulated that the meal chambers are not full, providing space above which allows evaporation to take place. The other method is to use the "three" or "four" high kettle, adjust the feed so

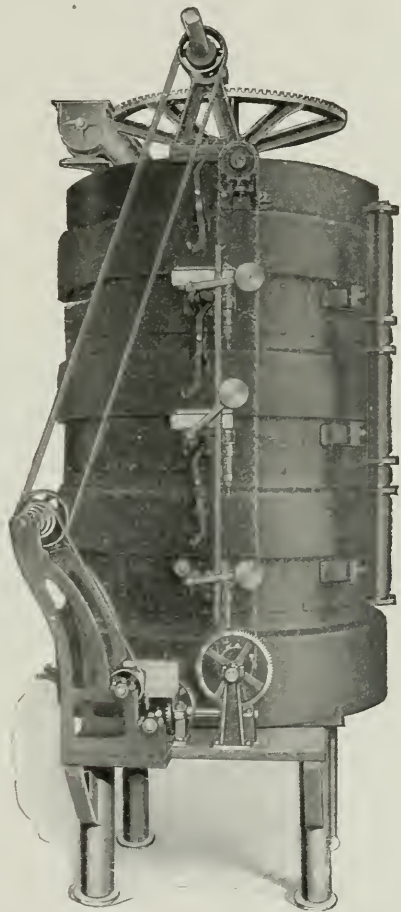


FIG. 2.—Upright Cooker

that the whole apparatus is full all of the time and admit no live steam at all except possibly when crushing old, dry seed which is hard to soften.

The factors entering into this operation are the speed of travel of the meal, and consequently time under heat, the temperature to which it is heated, and the amount of moisture present. If the time is too short the tissues are not thoroughly softened and the yield is low as a result.

When the temperature is low, the yield falls and the cake is brittle and easily broken; if it be too high the cake has a characteristic and undesirable odor and the oil will be dark and in certain uses will cause trouble.

Too little moisture yields a crumbly, non-adherent meal, which will not pack well and from which the cake is unsatisfactory. If too wet the meal is soggy, the oil contains an excessive amount of moisture and the cake will be dark in color and tough.

We have, therefore, three factors to co-ordinate in the tempering or heating of linseed meal. The only means of control are the senses of the operator. He takes a handful of meal and compresses it. If it has a certain "feel" under pressure, packs in a definite manner and oil can be started by the pressure of the hand, he says that it is well tempered. He modifies one or another of the elements of control when the cake or the meal varies from his standard.

Obviously the personal equation causes marked fluctuation. No two men are in complete accord upon fundamental principles. No accurate data are available, if indeed any exist, on which to base a system. Little is known of what really happens in the tempering operation. The theory is that the combined heat and moisture break down the walls of the oil cells, coagulate the albuminous sediment forming portions of the seed, and reduce the viscosity of the oil, thus making it possible for the flow to be more quickly and easily accomplished under pressure.

Of the mechanism of the changes within the ground flax seed, or of the manner in which variations in operation bring about the results noted in practice, little or nothing is known. It does not appear to be a difficult matter to apply scientific methods of observation during the process with the view of securing means of definite and positive control, so that variations in raw material may be made convergent in the meal cooker and so that uniform efficiency of extraction and uniform products may result.

From the bottom of the lowest compartment of the heater the meal passes into a metal box mounted on a runway over which it travels to the "former," a machine which measures the amount of ground seed to constitute the charge for each of the plates of the press and compresses it to a soft cake. These formers are actuated by hydraulic, by steam, or by belted power. The hydraulic type, the one commonly used, is operated from the low-pressure hydraulic system. At the end of the runway on which travels the meal box is a hinged flapper frame on a table which moves at right angles to the travel of the box so that it may be pushed back under the stationary part of the machine. This consists

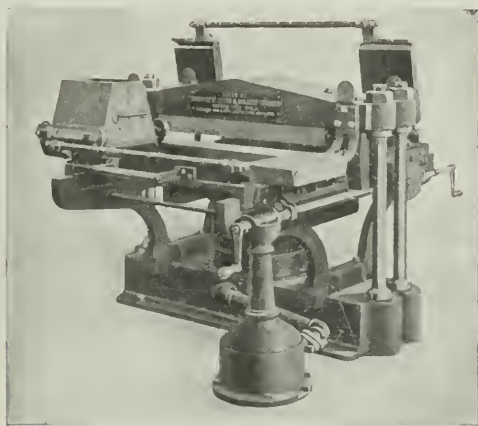


FIG. 3.—Hydraulic Cake Former

of a head block of heavy cast-iron supported by wrought-iron pillars, designed to withstand the upward pressure of a base plate actuated from below by a hydraulic ram. During the operation a slide gate in the bottom of the cooker is opened by hand to allow the box to fill with meal. On the table is laid the press cloth in a strip about 15 in. wide and 6 ft. long. The buggy box is now filled with meal and pulled out over the frame into which most of its contents fall. It is generally given two passages over the frame to insure an even filling of the space. Considerable skill is acquired by experience in the handling of the box in order to produce a clean uniform fill with the material evenly placed and of constant weight. The table is now pushed back under the head block, the power applied for an instant, then released, the table withdrawn and the

flapper frame is lifted. The ends of the cloth are thrown over the top of the formed cake when the pressman slips a sheet-iron pan slightly larger than the frame and equipped with a handle

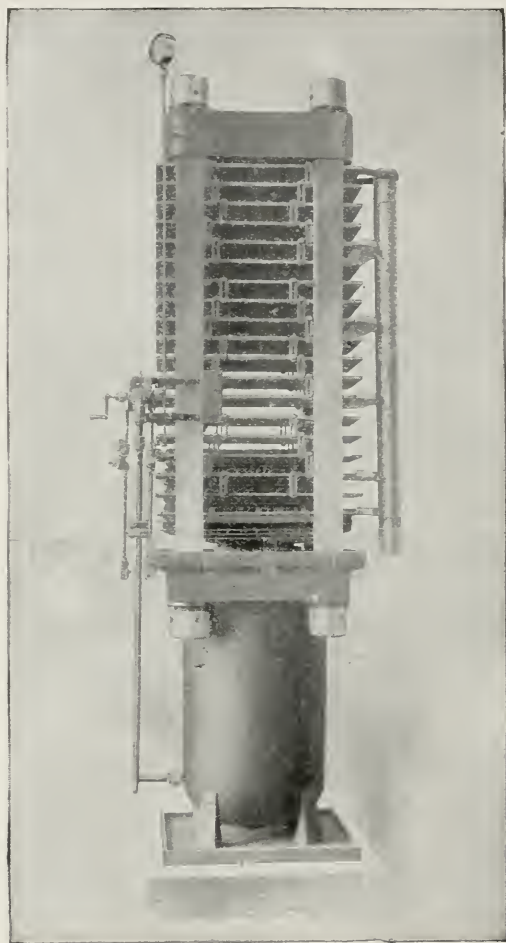


FIG. 4.—Open Box Press

on one end under the cloth and transfers the molded and wrapped cake to the press box. This type of former minimizes danger of injury to the operators, because it is practically impossible to get one's fingers in a position where they will be crushed.

To do good work a former must mold a perfect and compact cake that will fit the press boxes, must work cleanly, that is, not spread the meal out to litter up the press room, must make a cake sufficiently coherent to permit of necessary handling without loss of portions of it and must deliver a cake of uniform density and thickness, so that uneven pressure will not be caused in the press and cakes of uniform weight will result after pressing.

There is a mechanically operated buggy box in which the box is on the end of a piston actuated by hydraulic power. The machine lacks the uniformity resulting from the effort of a man interested in doing good work, because it will not run the meal box over the frame twice in order to have it evenly filled and thereby make a cake of uniform density. It doubtless, however, compares favorably

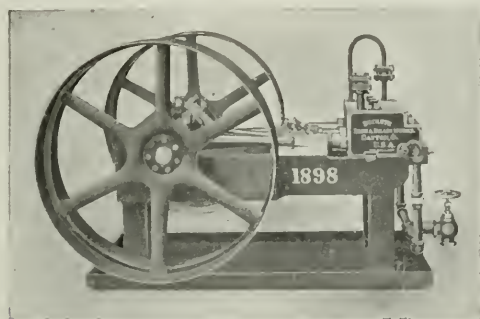


FIG. 5.—Four-crank Pump for Hydraulic Press

with the work of green or indifferent operators. It does not make a reduction in labor expended, because a man is required to operate this machine and to do the other work necessary to form and wrap the meal, just as when all hand power is employed.

The press used in the winning of linseed oil is the typical open plate hydraulic machine, the essential parts of which are: The cylinder and lower block, frequently cast in one piece; a stationary head block, which is bolted through to the lower block by means of heavy hammered iron columns; and the ram, on the end of which is placed a platen or heavy block rigid enough to prevent flexure at the ends, so that even pressure will be exerted over the entire plate area.

Hydraulic pressure is obtained from power driven pumps so equipped as to be capable of supplying both high and low pressure.

One of the most popular forms of pump is a four-crank design, furnishing both pressures. The hydraulic system consists of a supply tank for the liquid, which in this case is linseed oil, pumps, accumulators, valves, change cocks and piping. The accumulator consists of a mass of heavy materials superimposed upon a ram and guided in its vertical movement. Its object is to store hydraulic fluid, which is intermittently used, thus producing more constant

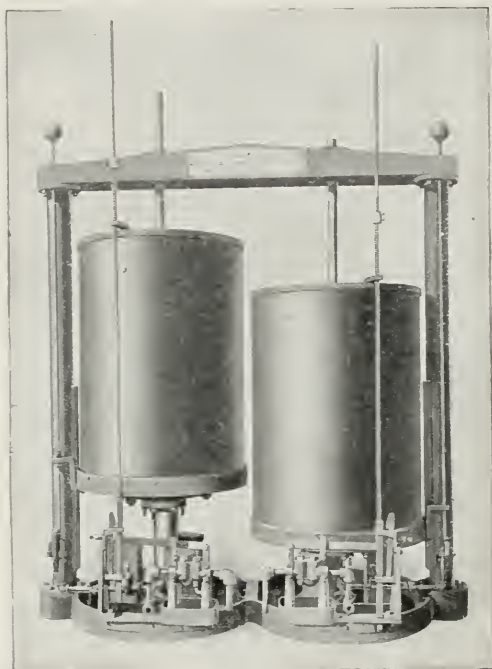


FIG. 6.—Accumulators. Double High and Low Pressure

load on the pumps, to steady the pressure by reducing shocks, which if severe, would injure the machinery and piping, and to act as a regulating valve to maintain a uniform pressure. Both the high and low-pressure systems have an accumulator. The low-pressure is used to start the working stroke of the press and to operate the "former," the packer, and possibly the other hydraulic machinery. It is usually set at 500 lb. per square inch. The high-pressure varies between 3500 and 4500 lb.

The regulation of the pressure is this: When there is no demand

for fluid the plungers work idly by circulating the oil through and back to the supply tank by means of the automatic movement of a valve from a system of adjustable rods and levers at the accumulator. When working fluid is again required, the by-pass valve is closed by the fall of the accumulator and the pump again delivers fluid at working pressure. When communication is opened to a press through an automatic change cock, the pressure is turned on to the ram only from the low-pressure accumulator. The press ram travels up rapidly until a pressure of 200 to 300 lb. is reached which is enough to start the oil. A choker in each pipe regulates the speed of the press by throttling the flow of the fluid. The ram travel is slowed down in proportion to the escape of the oil. When a pressure of 500 lb. is reached, the oil from the high-pressure accumulator is automatically turned on to the press ram. The speed of travel is again governed by a choker, so that the maximum pressure of about 4000 lb. is not reached until the ram is nearly at the end of its travel.

Press plates are at present generally made of rolled steel about $\frac{5}{8}$ in. thick. They were formerly made of iron or brass. The sizes of the plates vary, though in linseed oil manufacture they are generally designed to hold a cake 13 by 32 in. or 16 by 34 in.

Drainage is secured by cutting grooves or oil channels close to the edges of the plate which are pitched toward the rear, where they connect with down spouts that conduct the oil to the receiving troughs at the floor level behind the presses. Some presses are tilted back to give a fall sufficient to cause the oil to run in that direction.

Suspension of the plates, when pressure is released, is usually obtained by the use of links, each set of which carries the plates beneath, unless sectional supports are provided. The links are of two sorts, the plain open type, or the square, flat-headed type. The former are fastened to T-headed bolts screwed on to the edges

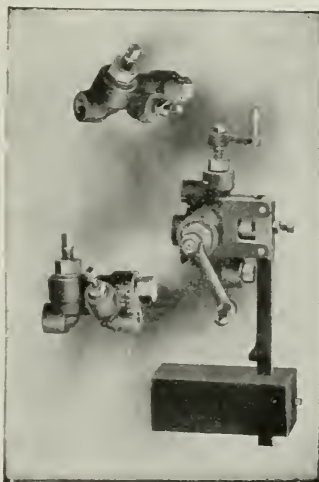


FIG. 7.—Automatic Change Valve and Choker

of the plates, while the others are slipped into notches cut in the sides of the plate near the ends. Often the plates are divided into groups so as to lighten the load upon the links. This is accomplished by having lugs on the plates which engage the heads of screws set at proper intervals in the columns. Another very effective method of support is by a step-ladder or inverted V-shaped device the feet of which are fastened into the columns near the bottom plate, while the top is attached to the head block at the center of each side. The legs of the ladder are of steel plate and are notched at measured intervals. Into each side of a plate are screwed two headless bolts so placed that each engages its own step of the ladder. Thus, each plate is supported by a rigid frame and the load caused by a group of plates is done away with. The wear on the steps is slight and easily adjusted for when the press is up the supporting frame can be removed and repaired without removing the plates, while when the links are used each plate must be removed whenever it is necessary to shorten them. It is important that the links be kept true for they control the space between plates, which must not fall below a minimum or the cakes cannot be placed easily. It is a too-frequent occurrence, especially in new mills, to have the cake space shortened by wear or lengthening of the links, so that the bottom cake is not easily put into proper position, causing uneven pressure and the breaking of the platen. It is false economy to reduce the cake space in designing a press, for time is lost during loading and cakes are not evenly placed, causing them to lie at angles instead of parallel to each other. This means uneven pressure and loss of oil. With ample working space, the molded and wrapped cake is quickly placed into proper position, thus lengthening the time of pressure and insuring even pressure throughout.

Primarily the capacity of the press is controlled by the number of plates comprising it, though variations in operation, to be discussed later, are factors of the capacity of any given press. The number of plates in the presses of American mills varies, generally, between 16 and 26. The obvious objection to the small presses is low capacity, for when reduced below 20 plates little, if any, gain in yield results. When the large 24- and 26-plate presses are employed it is hard to find men tall enough to reach the top plate and agile enough to place the bottom one quickly. A slight additional expense is noted with large presses caused by the de-

struction of the ends of the slip pans, which are broken by the exertion of downward pressure before they are entirely out from between the plates. When a large number of cakes are replaced the press is down a longer time, and consequently cooled more. The temperature of the press and its contents has an important bearing upon the yield, consequently the lower it drops the lower is the extraction. It may be said that the meal can be raised to a higher temperature, but this is an undesirable thing to do, for there is a limit beyond which meal ought never to be heated. Further, when the number of plates is large, there is a correspondingly great mass through which the pressure must be exerted. When this goes beyond a maximum, excessive cushioning occurs and low yield results. The extent of the loss caused by the use of large presses is an unanswered question, though one capable of easy solution. No data are available which shows, with all other variables constant, the effect that the increase in the number of plates has upon the yield of oil. What might be called circumstantial evidence, that is, the comparison of the percentages of oil in the cakes produced in mills known to have large and small presses, shows the latter to be more efficient. However, other factors enter which could account for the difference. It is the opinion of many versed in the operation of linseed mills that the 20-plate press combines the greatest number of elements that make for efficient extraction.

A much-mooted subject in linseed oil manufacture is that of press mats. These are mats woven from rope of coarse hair, such as that from the manes and tails of cattle. They are fastened to the plates which are often roughened to prevent slippage. Frequently the mats are attached to screens of coarse mesh and heavy wire, which are in turn made fast to the plate. Mats of malleable iron are also used, which are bolted to the plate. In many mills mats are used on both top and bottom plate, in others on but one and in still others none at all are used. The statement has been made that the mat was originally used to form a porous material through which the oil could run after leaving the meal. Practice, however, has proved that the presence or absence of mats makes no difference with the flow of oil. Supporters of the use of mats now claim that they tend to make the transmission of pressure equal at all points. If properly molded, the cakes will lie evenly on the plate and consequently be subjected to an even pressure without the assistance of a mat. It is also hard to see how a mat

can even up the exertion of pressure in view of the normal causes of that action. In answer to the statement that mats rigidly grip the press cloth, thus preventing slippage and uneven tension on it, can be placed the experience in two mills which has been directly communicated to the writer. In one there were two sections, one equipped with double hair mats and the other with none. After years of parallel operation, the superintendent made the statement that press cloth costs were the same in both cases. In another mill, strips of sheet-iron were placed over the mats with a consequent slight reduction in the cost of press cloth. Hair mats are poor conductors of heat, hence, it is said, the temperature of the meal will be reduced to a lesser extent during the pressing operation and, therefore, the yield of oil will be increased. In the previously-mentioned mill that section equipped with hair mats produced no more oil than did the bare plate portion. With only conflicting statements available and these based upon data doubtless modified by other variables effective during the period of observation, it is impossible to state positively what the hair mat does or does not accomplish. The objection to their use is cost. They are expensive and need frequently to be replaced. The mat does serve to guide the slip pan into proper position when the soft cake is slipped in between the plates, thus insuring equal pressure and parallel plates. The malleable mat accomplishes this without expense, save the initial cost. When bare plates are used they are corrugated or cut at right angles to prevent slippage while under pressure. Another objection to mats is that they are thick enough to appreciably reduce the cake space in a given column height. When bare plates are used there are fastened along the sides near the edge strips of metal beveled on the inside. These are to serve as guides in filling the press and also to prevent the meal from being pressed out at the edges. If they are made high enough to effectively guide the pan, they cut the press cloth.

One of the relatively large items of expense in linseed oil manufacture is that of press cloth, that is, the material which is wrapped about the cake when molded. It is usually woven from camel's hair because of the elasticity of that fiber and its ability to retain its strength and form under high pressures and temperatures. At present, this material is very high in price and is scarce as well. Various mats of wool and mixtures of wool and camel's hair cloth are being tried, but preference would still be given to the camel's

hair. Press cloth of human hair is now available. First tests of this showed up very well against camel's hair.

The avoidance of those elements of press room practice which make for the rapid destruction of press cloth is essential to good work. Trouble can start in the heater for water balls, or an uneven heating or wetting of the ground seed will gum up the cloths in spots, thus preventing the flow of the oil through them and causing disruption at that point. Meal not uniformly tempered does not pack evenly producing tension on the cloth. If too much moisture is in the meal as molded, it forces its way into the cloth, fills up the interstices with consequent tension and tearing,. Too high a temperature will reduce the tensile strength of the fibers and breaking will result.

If the "former" does not produce a cake of uniform density, the uneven packing in the press causes stresses which result in torn cloth. The press room foreman must watch the rate of ram travel after the oil begins to flow, for if it be too fast, the volume of oil set free, much of which passes to the edges through the cloth, will tear it. This must be watched with extreme care when the pressing takes place at a low temperature as in starting up after a shut down.

The torn cloths are darned, patched, mended, and pieced until the waste comprises short strips which are beyond redemption. These are but typical causes for too rapid destruction of press cloth. Constant watching by intelligent men is necessary to keep down this item of expense.

In the pressing of the tempered meal in a given press there are three variables which are functions of yield and capacity, one is the pressure. That most generally used is from 3500 to 4500 lb. per square inch. A gauge should be placed on each press, so that close watch can be kept for unexpected variations. Another variable is the weight of the molded cake. Practice varies between those weighing 10 lb. after pressing and those of 15 or 16 lb. When the cakes are thick, the mass of meal under pressure is great, there is more tendency toward uneven packing and the cushioning in the press is at a maximum. As, in the case of the number of plates in a press, there are no authentic data available on the effect of variations in the cake weight upon oil yield, so again we draw our conclusions from the analysis of light and heavy cake without knowing that weight was the only variable. The light cake give

the lowest average oil content. The minimum weight produced is 10 lb. To keep as close to that as possible is good practice. The third variable is time. The presses are usually arranged in groups of six, one of which is operated by the two or three men who work together. Assuming such to be the case, the pressings per hour are expressed as six on six, seven on six or five on six, as the case may be. In the first case the pressure is exerted for sixty minutes less the time required to discharge and charge, which varies between five and ten minutes with the dexterity of the men. The seven on six method allows but fifty-one minutes, while five on six permits of seventy-two minutes under pressure less changing time. In a mill which operated six on six part of the year and seven on six the remainder, a careful analysis of the cake produced is always kept. A tabulation of these figures for a period of several years showed that the longer time decreased the oil in the cake by one-half of one per cent. With cake at \$30 per ton and oil at 50 cents per gallon, one-half per cent reduction in the oil content of the cake makes a gain of 2.6 cents per bushel of seed, or \$3.25 per press per day, when it is run for yield and not capacity. To-day the figure would be about 9 cents per bushel.

As a result of a study of the data at hand, supplemented by experience, the writer would use, with the feeling that he was not far from the most economic practice, one roll for each two presses, an 84-in. 3 high heater for 12 presses, or possibly a 72-in. to six presses, a hand-operated hydraulic former, and 20-plate presses, in which 10-lb. cake would be produced at the rate of six pressings per hour on each six presses.

The obvious conclusions to be drawn from the statements made is that the manufacture of linseed oil is controlled in an uncertain empirical manner. It is possible that a system could be worked by accurate observations of the effect of various changes in operation and by a scientific study of the underlying reactions and mechanical principles involved which would minimize the effect of variations in the seed and thus render extraction more efficient. With the present and probable prices of oil and cake for the near future one would not have to make much of an improvement to pay large dividends upon the investment required.

When the cakes are removed from the press they are stripped, that is, the wrappers are removed. This is done either by hand or by machine. It is hard, disagreeable work, for at the start the

pull is mostly on the fingers and the cake is hot. The mechanical strippers in use simply catch the end of the cloth when it is placed in contact with a revolving shaft, about which it is wound.

The stripped cake is now sent to the trimmer, where the soft edges of high oil content are cut off. Trimmers are of two types, those with revolving knives and those with stationary knives, both having spring tension devices. There is little choice in the effectiveness of the machines. The rotary knife takes more power and is more complex, but the trimmings from it do not need regrinding, while those from the stationary knife machine do.

The depth to which to trim depends upon local conditions. It should be determined at each plant from its operating cost, so that the yield of oil from the trimmings when recrushed will be great

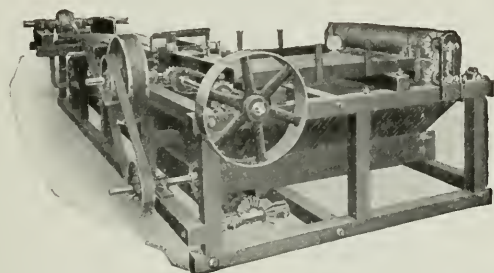


FIG. 8.—Automatic Cake Stripper and Trimmer with Disc Knives

enough to repay the expense of handling. If trimmed too deep the oil content will be so low that the oil recovered will cost more than it is worth, while if too much oil is left in the cake by shallow trimming, oil loss results. About 12 per cent oil in the trimmings is right when normal conditions obtain.

If to be sold as such, the cakes are packed generally in second-hand sugar bags, and shipped. A hydraulic machine takes a pile of cake from the trimmer and pushes it into a bag which is loosely filled, then the bag is placed under a packer which jams single cakes into it until the strain is near the breaking point.

When ground to meal, the cakes are run into an impact mill direct, or into a breaker and then an attrition mill. The first method is generally considered the more economical.

When the oil runs from the presses it is caught in settling troughs or deep metal boxes, in which coarse particles settle to the

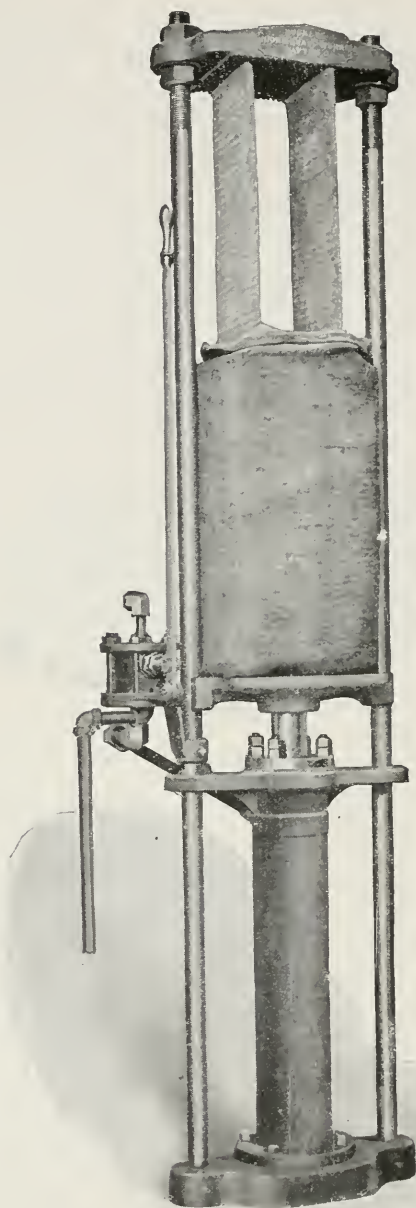


FIG. 9.—Hydraulic Cake Sacker

bottom. From here it goes to filter supply tanks. Filtration is accomplished by the plate and frame press. The filter medium varies from light sheeting to heavy duck and from light to heavy paper. At some mills the oil is filtered warm through cloth, sent to storage and then refiltered just previous to shipment. With many the second filtration is omitted. Others allow the oil to cool without the first or, as it is termed, "scalping" filtration, and then pass through cloth or paper.

Any one of these practices will remove the suspended particles of seed and deliver a clear oil. However, moisture and materials taken into colloidal solution from the seed are present in larger amounts in warm oil. They gradually precipitate as the temperature falls, forming what is known in oil parlance as "foots." Therefore, the temperature of the oil at time of filtration is an important function of its quality. If single filtration is determined upon, excellent results may be had by allowing the oil to cool and then passing it through cloth or paper, preferably the latter.

The quality of raw linseed oil is, obviously, dependent upon the manner of its filtration. Further, too high a temperature in the heater darkens the oil and causes it to dissolve more material from the seed. A hot-pressed oil will darken more under heat, will not bleach so well in the refinery, and shows other deleterious effects of the high temperature.

The quality and cleanness of the seed have a marked influence as well. Seed selection for oil quality is unknown, because no means at present exist to connect the characteristics of perfect flax seed with the quality of oil contained.

An investigation of this problem is at present under way. We are hopeful of results that will enlighten us upon the effect of seed strain, soil, and climatic conditions, upon the quality of oil and possibly enable prediction from an examination of flax seed of the quality of its oil.

Damaged seed, foreign oleaginous seed, and chaff or weed seeds capable of yielding coloring or other matters soluble in the oil are detrimental to the quality of the raw oil.

The manufacturers employing linseed oil demand of some of that product specific qualities, such as, pale color, high content of fatty acids, proper action in the varnish-kettle and high speed of polymerization when subjected to high temperatures. These qual-

ities are imparted by chemical treatments of various sorts which are more or less secret and which involve only simple mechanical equipment and operation.

The yield of oil is, naturally, dependent upon two things, the amount of it in the seed and the efficiency of the extraction.

During the last five years the average oil content of clean seed received by a mill on the seaboard was 39.02 per cent. North American seed comprised 75 per cent of that crushed, the rest being South American. Assuming that the cake will contain 5.5 per cent, an amount attainable by good practice, the theoretical yield of a cake will be 36.15 lb. and of oil 19.85 lb., or 2.64 gallons of $7\frac{1}{2}$ lb. each. The word "theoretical" is used because there is a manufacturing loss of about 2 per cent. This is nearly all due to the evaporation of moisture, though some is accounted for by soakage, dusting and similar causes. If the moisture in the seed is high, the loss will be above normal for oil carries very little water so the cake must contain all that is in the seed or a loss is inevitable.

DISCUSSION

Dr. DAVID WESSON: As Mr. Pickard has said, the treatment of linseed is so much like the practice in the manufacture of cotton seed oil, you would hardly know the difference. In listening to Mr. Pickard's paper one would almost imagine it was written on the practice of treating cotton seed. We have a great many of the same problems in cooking the seed and in getting the yield of oil out of them. I think perhaps we have made some progress in regard to cooking the seed. There have been some excellent heaters put on the market lately which turn out a very uniformly cooked seed. They are made by the French Mfg. Co. of Piqua, Ohio, and as they give splendid results on cotton seed, they would probably do the same thing for linseed.

The treatment of cotton seed is affected by heat very much the same as linseed is. We have to be very careful not to heat the seed too much and at the same time we have to be very careful not to dry them out beyond a certain point and to have them in just the right temperature for the presses. Up to a very comparatively recent time, there has been no good way to control the cooking, except to take a handful out and squeeze it to see if it feels right. Even then, with the greatest care, we sometimes run

into a lot of seed that we are simply up a tree to know how to handle properly. In other words, a rule that works beautifully one minute may go all to pieces the next, and from the analysis of the seed we may not find any reason why there should be a difference. Of course, we have to consider more particularly, I imagine, the effects on refining than might be the case of linseed oil, because food products require bleaching right up to the minute and one cannot be too careful not to injure the bleach in the process of cooking and pressing.

I do not know as I can say very much more without going into a lot of minor details.

Dr. WILLIAM P. MASON: May I ask how hard you squeeze it, and what does it feel like when it feels right?

Dr. DAVID WESSON: It feels just like a hasty pudding. It does not have too much water in it. In other words, to be a little more explicit, it should not feel sandy. If the meal is cooked too much, if you take it in your hand and squeeze it, it will feel just as though it had a lot of sand in it. It should just come together and pack nicely. I have seen meal come out of the cookers that you could squeeze oil out of in your hand.

The CHAIRMAN: I remember a good many years ago, in considering the question of the unequal distribution of oil in the cake I took a linseed cake and laid it off in 2-in. squares and then with an augur bored a hole through the cake in the center of each of these squares, and each one of these samples showed different analysis, and it was astonishing the variation which existed in the amount of oil, and it demonstrated one thing, that good practice means that you must produce an oil cake that is as even in thickness throughout as possible. What you may lose in one place you do not recover in another place. If you happen to leave a large amount of oil in one place that is not compensated for by a greater amount in another place. And the use of old mats which have become knotted and worn is rather poor economy. A mat that gives an even surface—I should say a cloth—but it applies also to a mat, that gives an even surface will give good yields. On the other hand, if you get a cake which is unequal in thickness in parts, you do not get an average good yield.

INDUSTRIAL WASTES DISPOSAL

By HARRISON P. EDDY *

Read at the Buffalo Meeting, June 20-22, 1917

While there are various waste materials resulting from the industries, the term "industrial waste" has come to mean the liquid wastes from the processes employed in industrial establishments. In England they are called "trade wastes"—a term not quite as applicable in this country, although occasionally used. Neither the human excrement of operatives nor their wash waters are comprehended in this term, although in many cases there is no effort to prevent their admixture.

Origin of Industrial Wastes.—Many industries employ great quantities of water for various purposes such as condensing, washing of raw stock, dilution of chemicals, transportation and application of materials, and the washing and rinsing of finished products.

Some of these uses do not defile the water and it can be discharged at will, as for example many condenser waters. Other uses result in a very great change in the character of the water and render it unsuitable for discharge into some waterways.

In paper mills after the digestion of the raw stock with strong chemicals, there remain the liquors, highly charged with mineral and organic substances, but for which the manufacturer has no further use. He therefore seeks to get rid of them in the most expeditious and least expensive manner. The fibrous stock is then washed, and large quantities of wastes are discharged from the washers, more or less highly charged with substances like those already mentioned. From the paper machines come great quantities of water carrying fine fiber, clay, coloring matter, and other substances depending upon the character of paper made and the processes employed.

In tanneries pure water is indispensable, but after use it is highly colored, charged with spent chemicals, and loaded with organic

* Of Metcalf & Eddy, Consulting Engineers, Boston and Chicago.

matter. Its burden of impurity is partly in suspension and partly in solution. Wastes from different processes within the same tannery often react upon one another, throwing out of solution substances which in their new physical condition may be deposited in waterways to their detriment. Some tannery wastes of themselves are so resistant to bacterial action that they do not readily putrefy, yet when diluted with the waters of a natural stream, they may become most offensive.

The wastes of woollen mills vary radically from those of paper mills and tanneries, yet they may be the cause of just as serious complaints. The grease and soaps from the scouring of the wool, the spent dye liquors, the soaps from the cloth-washing and the rinse waters in the aggregate, are of great quantity, highly colored, turbid, charged with suspended matter and quite capable of transforming an attractive stream into an unsightly, foul-smelling, and quite unattractive waterway.

Instances like the foregoing might be multiplied almost without end. Some of the other industries which have encountered difficulties in the disposal of wastes are wire-drawing and galvanizing works, carpet mills, dyeing and leaching works, strawboard factories, slaughtering and packing houses, breweries, distilleries, gas works, chemical and explosive works, and mines and coal washing plants.

Effects of Wastes upon Waterways.—The ingredients of industrial wastes may be grouped in three main classes:

Floating and suspended matter.

Substances in solution, in colloidal condition, and in an extremely fine state of suspension.

Bacteria.

Floating and suspended substances may render the waters into which they are discharged, unsightly, and cause deposits. Such deposits, if of organic matter, often deprive the overlying water of a large proportion of its natural content of dissolved oxygen which is necessary for the maintenance of biological equilibrium and the prevention of putrefaction. Decomposition is accompanied by the generation of large quantities of gas, some of which is entrained in the mud until it has accumulated sufficiently to enable it to buoy up large masses, which may be seen floating for a time upon the surface of the water, only to be broken up and redeposited upon the liberation of the gases.

Dissolved substances almost always accompany the suspended matter in industrial wastes. Sometimes they are much more troublesome. They, too, cause the depletion of the oxygen supply, usually through the action of the bacteria of decomposition. Particularly objectionable and difficult to treat are those wastes containing large quantities of very finely divided suspended matter, and colloidal substances. Usually impurities of this class pass along with the waters of the stream into which they are discharged and do not form deposits. However, under some circumstances such ingredients are coagulated and thrown down, sometimes by the reaction of wastes of one process with those of another, and at others by natural physical, chemical, and biological processes going on in the waters.

Most industrial wastes contain bacteria. These may not be pathogenic germs. In fact, they may be decidedly helpful in the problem of disposal, rather than harmful. There are abundant opportunities in some of the industries, however, for the pathogenic organisms to escape in the liquid wastes and thus contaminate the waters into which such wastes are discharged. One of the most dreaded organisms which may be spread about in this manner is the anthrax bacillus, sometimes present in hides, skins and wool. This organism is very hardy and appears to maintain its virility through its spores for many years.

Excrementitious matter from operatives is often combined with the industrial wastes, and thus the entire flow may be rendered bacterially dangerous.

Wastes may cause objectionable conditions in many ways, depending upon their character and the size and condition of the waterway into which they are discharged. They may contaminate a water supply, render a stream unsightly and objectionable in appearance, cause putrefying deposits, render the natural waters putrid and offensive, poison or otherwise kill fish, and injure vegetation. Strange and contradictory as it may sound, complaint is frequently made that wastes are killing vegetation and about equally often that they are so encouraging the growth of vegetation as to do serious damage. If one complaint doesn't apply, the other usually does.

It might appear that, as the industries are the offenders in this field of activity, there would be few complaints from them of the conditions produced by the discharge of industrial wastes. Just the contrary is true. One of the most common complaints comes

from the manufacturer to the effect that an upper riparian industry is rendering the water unfit for use in his plant.

Selection of Factory Sites.—Enough has been stated to show how widespread is the trouble in disposing of industrial wastes. When about to establish a new industry or plant, the proprietors usually make thorough investigation of the quality of the water available for their use. The extent of the supply is also generally investigated and often such collateral questions as the amount of power derivable from the passing stream. But how infrequently do they make even a superficial study of the problem of wastes disposal. Yet this may be a greater and more difficult problem than that of water supply.

Expenditures of \$100,000 or \$200,000 for wastes treatment plants and of \$25,000 to \$40,000 annually for the operation of such plants are becoming more and more frequent. Capitalizing the annual expenditure of \$25,000 at 5 per cent and adding \$100,000 for construction cost, making no allowance for depreciation, it appears that the industry might have expended as much as \$600,000 in procuring a site which would not have entailed the necessity of wastes treatment.

The selection of a suitable site for an industry producing large quantities of wastes is a matter of much importance. Even though conditions at the outset appear to be favorable, they may be materially altered by establishment of new industries down stream or by an increase of riparian population below the plant.

Treatment of Wastes.—When it is impracticable to afford the wastes sufficient dilution to prevent the production of unsatisfactory conditions, it becomes necessary so to modify the character of the wastes that they will not cause complaint.

One often hears that wastes cannot be so treated; that if a way were known the manufacturer would gladly adopt it. This impression that the wastes cannot be successfully treated is in many cases not true and it may be accepted that they can be so treated as to remove their objectionable and deleterious properties before their discharge into natural waterways.

On the other hand, such treatment may be and often is a very expensive undertaking and one from which the manufacturer naturally shrinks on this account and also because he personally is not familiar with the process or processes necessary to the accomplishment of the object.

Perhaps the most important step in the solution of this problem is the determination of the extent of treatment necessary to meet the requirements of the case. To answer this question intelligently it is necessary to know the character and quantity of the wastes produced, the character of and conditions surrounding the waterway into which they are being discharged, and their effect upon the waters in question.

The next step is to determine how best to treat the wastes to accomplish the necessary results at a minimum cost and, in any event, one which is not prohibitive. There have been instances when the plant proposed for such treatment would have cost a sum about equal to the value of the entire industrial plant of which it was to become a minor part. Such a suggestion is absurd and tends to reduce or extinguish the respect of the manufacturer for the party making the suggestion, for the officials trying to enforce the laws, and even for the laws themselves.

The impurities may be classified again as suspended and dissolved matter and bacteria. For the removal of the suspended matter screening may suffice under some conditions, while others may require the more complete removal by sedimentation. When the substances in suspension are of very light specific gravity and finely divided, it may be necessary to resort to chemical precipitation.

Some dissolved matters may be removed by chemical precipitation, while others can be modified in character by chemical treatment without actual removal. If they are organic and subject to putrefaction, bacterial action may be required for their oxidation as in sewage treatment.

Certain wastes are bacterially dangerous and it may be necessary to destroy the pathogens even where the suspended and dissolved matters would cause no harm. In such cases the treatment of the wastes may be all that is essential, while in others it may be necessary even to treat the raw material, as has been suggested in the case of anthrax-infected hides.

It should not be inferred from this discussion that a single process can be selected for each case, for it often requires several to accomplish the desired result.

At one plant where the author's firm has supervisory charge of the wastes disposal department, no less than seven steps have been employed at one time. These are degreasing of a portion of the wastes, sedimentation of the wastes, chemical treatment of

the settled effluent, filtration of a portion and dilution of the remainder of the chemical effluent, and finally the introduction of chemicals to prevent the exhaustion of the supply of oxygen in the river.

Variation of Treatment from Time to Time.—The process adopted should, in many cases, be varied from time to time to take advantage of favorable or to offset unfavorable conditions. The volume of business being done may materially affect the quantity of wastes produced and correspondingly make the condition dictating treatment more or less exacting. Industrial processes frequently are changed, requiring modification in the treatment methods.

In winter the temperature may be sufficiently low to retard or even prevent putrefaction under conditions which in summer would transform a natural waterway into a stinking slough.

In spring there are usually large volumes of diluting water which may make bacterial oxidation in filters unnecessary, at a time when the filters would be working under most unfavorable conditions.

All of these and innumerable other conditions must be taken into consideration if success is to be attained at a minimum cost.

Advisability of Anticipating Complaint.—In many cases industrial establishments which are now of great size have grown from very modest beginnings, often from merely a room or two adjacent to a water privilege, which was the primary reason for the selection of the site. As the business has grown through the decades, conditions have entirely changed. What was an abundant supply of water not only for industrial purposes, but also for the dilution of the wastes, has now become barely adequate for industrial purposes alone and the entire flow now passes through the plant and perhaps through several plants more recently built. Thus the entire stream has become a river of industrial wastes rather than, as originally, a natural river into which a minor quantity of industrial wastes was discharged.

In all such cases there has been a collateral increase in the resident population. Now there are villages along the river where formerly were wooded lands and pastures. Such development has brought with it demands for parks and other recreation facilities, including the improvement of the natural stream for boating and perhaps for bathing purposes.

Under some conditions a proscriptive right may be acquired to make certain uses of the waters of the river, even though they

be more or less hostile to the enjoyment of some privileges by lower riparian owners. The proscriptive right is often advanced in defense of the practice of discharging untreated industrial wastes into waterways and their consequent pollution. Many of the industries, particularly in the eastern part of the country, are of very long standing. The continuous operation of an industrial plant devoted to the same general kind of work for more than a century, can be cited in numerous instances. In comparatively few cases, however, can it be shown that such industries are operating under conditions substantially indetical with those of prior decades. Either the character of the business has changed so that processes are different and industrial wastes are greater or less in quantity and decidedly altered in character, or the business as a whole has become much greater with a corresponding increase in the quantity of industrial wastes. These changes make it exceedingly difficult in most cases to establish a proscriptive right to the acts of which complaint is made.

It should be borne in mind that in no case can one acquire a right, by proscription or otherwise, to create a nuisance. This fact has been the stumbling block upon which many an effort to secure or maintain privileges, through court decisions, has been defeated.

The paramount lesson to be gained from experience in these matters is that it is wise to anticipate complaint of objectionable conditions whether from lower riparian manufacturers influenced by difficulties caused by the character of the water, from a community complaining because of odors and objectionable appearance of the stream, or from the farmer whose cattle will not drink the water, whose crops are killed because of inundation by polluted waters, or whose ditches and natural brooks have become so overgrown with vegetation due to the fertilizing ingredients of the water having their origin in industrial wastes, that they will no longer serve their purpose.

The prudent manufacturer will make it a part of his routine business carefully to observe the effect of the discharges from his plant, upon the character of the water in the river, not alone in his immediate vicinity, but for a considerable distance downstream. When conditions become noticeably objectionable, he will take measures to remedy them, at the same time maintaining the valuable privilege of utilizing the stream for the disposal of his wastes,

to as great an extent as is compatible with the public good and the reasonable use of the waters by lower riparian manufacturers. Such a policy, if intelligently pursued, will result in many cases in avoiding expensive litigation. More important than this, however, is the fact that by maintaining the waterway in a reasonably satisfactory condition, the hostility of lower riparian dwellers may be avoided. Where such a feeling is aroused by objectionable conditions, it may exert itself through legislation or through litigation in such a manner as to require the establishment of exceedingly rigid restrictions as to the use of the river or even drive the industries away. Numerous instances of the latter can be cited.

Neponset River an Illustration.—One of the most interesting illustrations of the industrial wastes disposal problem is that of the Neponset River Valley, near Boston in Massachusetts. This river rises about 22 miles from Boston Harbor, into which it discharges. Its natural drainage area is 114.14 square miles and it also receives one-third of the flow of the Charles River at Dedham, equivalent to the drainage from 66.2 square miles. The total tributary area is therefore 180.3 square miles.

The normal yield of the drainage area is probably about as follows:

Month	Mil. gal. daily	Cu. ft. per sec.	Month	Mil. gal. daily	Cub. ft. per sec.
January.....	216	334	July.....	31	49
February....	304	470	August.....	45	69
March.....	492	762	September..	40	62
April.....	356	551	October....	76	117
May.....	190	294	November..	135	209
June.....	84	130	December..	176	272
			Mean....	178	276

The actual flow is much more uniform than the natural flow would be, because of the regulating effect of the storage reservoirs.

The State Department of Health reported at one time that there were about 30 mills discharging more or less wastes into this river. Before prohibitory statutes were passed, one wool-scouring concern abandoned its location. Some manufacturers have diverted a portion of their business to other plants and one has abandoned the manufacture of one line of goods, thus avoiding the production

of a large quantity of liquid wastes which were very difficult to treat.

Eleven manufacturers have provided sedimentation tanks and ten have constructed strainers and filters of cinders, coke, or sand. Some have adopted chemical precipitation as a means of improving the efficiency of natural sedimentation. Treatment plants have been provided in nearly all cases where the wastes require treatment, some of which were described by the writer in a paper entitled "The Cleaning Up and Improvement of a Stream Polluted by Sewage and Trade Wastes," published in *Engineering and Contracting*, August 9, 1916.

In 1902 the Massachusetts Legislature passed an act directing the State Board of Health

"... to prohibit the discharge of sewage . . . or every other substance which may be injurious to public health or may tend to create a public nuisance or to obstruct the flow of water, including all waste or refuse from any factory or other establishment where persons are employed, *unless the owner thereof shall use the best practicable and reasonably available means to render such waste or refuse harmless.*

"Section 2. The Board shall consult and advise with any such owner at his request or of its own motion as to the best practicable and reasonably available means of rendering such waste or refuse harmless, having regard to the circumstances and requirements of the situation and to the industrial interests involved." (Chap. 541, Acts of 1902.)

It is interesting to note that it was the intention at the time this original act was passed, to have reasonable regard for the manufacturing industries, not requiring them to go to extremes in the treatment of their wastes unless the exigencies of the situation required. In other words, incorporated into this statute was the "rule of reason."

At the time of the passage of this statute industrial wastes treatment in this country was in its infancy and progress in improvement of conditions in the Neponset Valley was naturally somewhat slow. In 1906 it appears that public sentiment had been so aroused that it was possible to pass an act in which the "rule of reason" was much less evident than in the earlier act. The only reference to it in the 1906 act was that the Board was to advise the owner of the factory as to the "*best practicable and reasonably available means of rendering the wastes or refuse harmless.*" The clause "having

regard to the circumstances and requirements of the situation and to the industrial interests involved" was omitted from this act.

During the next ten years many efforts were made to secure additional and usually more drastic legislation, in spite of the fact that the manufacturers expended large sums of money in an effort so to modify their wastes before their discharge that they should not endanger the public health nor tend to create a nuisance. Perhaps the culmination of these efforts may be said to have been embodied in a proposed act—Senate 113—presented to the Legislature for its consideration in the year 1916, which read as follows:

"Section 1. Any person, firm, corporation, or group of individuals who shall cause, either directly or indirectly, the pollution of the waters of any river in this commonwealth, shall be punished by a fine of not more than one hundred dollars for every day which said pollution continues after notice from the health commissioner that such nuisance be abated.

"Section 2. A river shall be held to be polluted within the meaning of this act whenever by the introduction or discharge into its waters of any foreign or deleterious substance: (a) it shall give out any noxious or offensive smell, odor or vapor, which condition is a menace to the public health; (b) it shall become discolored in such a way as to be unsightly or offensive; or (c) it shall become poisonous or dangerous to fish or animal life subsisting therein, or to live stock using the same as a drinking place; (d) it shall become injurious to vegetation in its vicinity.

"Section 3. The health commissioner of Massachusetts shall be charged with the enforcement of the provisions of this act and shall determine when the waters of any rivers are being polluted as aforesaid.

"Section 4. All acts or parts of acts inconsistent herewith are hereby repealed."

There are several provisions in this act which would be exceedingly oppressive if applied with literal interpretation of the act and without reading into it the rule of reason. One of these is the provision for a fine not to exceed \$100, for every day which the pollution continues after notice from the Health Commissioner that such nuisance be abated. In some instances, even if prosecuted with diligence, plants for the elimination of those ingredients of wastes which caused the pollution could not have been built in less than six months' time.

Aside from the broad scope of the specifications of a polluted river within the meaning of this act, the Health Commissioner was charged with its enforcement and apparently made the sole judge

to determine when the waters of the river were being polluted, as specified by the act. Should such an act be found constitutional, which is subject to some doubt, it would apparently deprive the alleged offenders of their rights to a hearing before the courts of justice.

Happily this act was not passed and is introduced here merely as an example of the extent to which industries or communities may go after they have become thoroughly aroused by long-continued objectionable conditions. It is confidently believed that such drastic legislation can always be avoided and probably also its suggestion forestalled, by prudent foresight on the part of manufacturers in preventing objectionable conditions caused by the discharge of their untreated wastes.

Program for Solution of Problem.—In many cases where manufacturers have been confronted with a serious problem in connection with the disposal of their industrial wastes, they have been inclined to attempt its solution without first acquiring a clear understanding of the scientific principles involved, either in the production of the conditions which caused the trouble or in the processes available for the treatment of the wastes to render them less objectionable. The treatment of industrial wastes usually is a subject entirely different from that with which the manufacturers have to deal in their usual business and in which they are primarily interested, all other matters such as the treatment of their waste liquors being of only secondary interest and importance from their point of view. They have, therefore, often adopted a plant poorly adapted to the use they desired to make of it. Sedimentation tanks, for example, are often found which are entirely inadequate for the purpose, although this process is most simple. All sorts of filters have been designed and constructed, but usually without the remotest conception of the scientific principles involved in the treatment which they were intended to accomplish.

Another fruitful source of misdirected energy has been the desire to recover from the wastes ingredients of value such, for example, as the grease and fertilizing ingredients in municipal sewage. Industrial wastes, like sewage, often contain ingredients which have a market value, and every encouragement should be afforded to the recovery of such products. As economic conditions change in the future there will be a greater need of economizing in this direction, and it is to be expected that processes will be devised

for the profitable recovery of such ingredients. The fact that such processes may not be available at the time the problem first presents itself, but will probably be available at some future time, is not a justifiable reason for making no effort for its solution.

Whenever an industry is confronted with a problem of this kind a program for its solution should be carefully worked out before making expenditures upon construction. In fact, the studies necessary to the preparation of such a program may disclose other means of solution, involving relatively small cost.

First a study should be made of the waterway, to note its condition and physical characteristics, such as size, velocity of flow, depth and temperature, and a similar study of wastes to determine their quantity and character. With the information gained in this manner it will be possible to form an opinion as to the extent of treatment required to meet existing conditions.

Next, the kind of treatment and the plant required to provide such treatment, should be determined. The methods selected should be those required to give the results which may be desired within a reasonable period of time in the future when perhaps conditions have become decidedly different from those obtaining at the time the investigation is made. Such methods should always be selected and reported with the clear reservation that new and better processes may be subsequently devised.

Following the selection of methods should be the construction of plant. Here it may be wise to proceed progressively, building first the system of drains required for the collection of the wastes and for their discharge at a single point. After this has been done further investigations based upon the measurement and analyses of the combined wastes, may be desirable. When the collecting system shall have been completed, it will be possible to provide the first part of the treatment process, such, for example, as screening or sedimentation. After this has been accomplished still further investigations may be desirable to determine, first, the efficiency of the plant already installed and, second, the next process of treatment which should be provided and the probable results to be obtained.

However much or little may be required, it is important to build in accordance with an intelligently devised plan and in harmony with such additional processes as may follow. Thus many expensive mistakes will be avoided and advantage taken of all

opportunities to provide an economical arrangement of plant. The following of such a course will often result in avoiding expensive pumping of the wastes, or the treatment of excessive quantities due to the inclusion of relatively clean waters which may not require treatment under the local conditions.

The final step, and undoubtedly the most important, is the intelligent operation of the plant. Whether the processes involved are simple or complex, the supervision and control of operation should be based upon a knowledge of the conditions in the river, the character of the wastes and the scientific principles involved in their treatment. The object to be attained and extent of treatment necessary at the time of its accomplishment should be kept constantly in mind. Many thousands of dollars in the cost of operation may be saved in this manner.

DISCUSSION

Mr. H. P. EDDY: Mr. Chairman and gentlemen of the American Institute of Chemical Engineers, when your Secretary asked me some months ago if I would prepare a paper on the disposal of industrial waste I said that I should be pleased to do so, but wrote to inquire what phase of the subject he would like to have me discuss. After some correspondence it was decided that I would make the paper rather general in nature and therefore perhaps find someone who would be interested in some part of it. The particular problems in connection with the disposal of industrial waste are as varied and diversified as the wastes themselves, and I have tried to deal tonight with this subject in a very general way, laying down certain principles which I think are applicable to all or nearly all of the problems.

THE CHAIRMAN: The paper by Mr. Eddy is now before you for discussion.

Dr. WILLIAM P. MASON: Mr. Chairman, it is always a great pleasure to listen to Mr. Eddy speak on a subject such as this because he certainly knows what he is talking about.

I was very much interested indeed when he referred to the question of anthrax and could not help but feel that there is a little matter with reference to that particular organism that is especially disheartening. It is such an easy thing to get your medicine used up when you attempt to treat the difficulty. Suppose,

for instance, you have decided to use chlorine. Organic matter which is present in the trade waste is a very variable quantity, when you are dealing with tannery effluent, and if you make up your mind to employ a specific dose it may well be that the dose of yesterday will not do at all for the waste of to-day. The material present in waste from a tannery may use up an amazing amount of chlorine and there is nothing left for killing the organism you are trying to get rid of.

I was interested again in the reference he made to the straw board mill. Some years ago I had to do with a case of water supply for a mill making postal cards. This mill had a quarrel with a straw board mill up the stream and considerable work was done in collecting data to aid our cause in attacking the said straw board mill and in showing how the waste from the upstream establishment ruined our product, when suddenly the contract to supply postal cards for the Government ran out and a renewal was sought. Of course it was then in order to show the Government that we were in a position to supply good material for postal cards, and of course the case against the straw board mill had to be discontinued.

I should like to ask Mr. Eddy, to tell us if he will, something about that particularly elusive trade waste known as the red liquor from the sulphite pulp mill. What we are going to do with that?

MR. H. P. EDDY: I think one of the most valuable parts of meetings is the discussion, because it brings out two things: one is what we know, but the principal one is what we don't know, and that is where my part in this discussion ends. (Laughter.)

THE SECRETARY: It might be interesting to say that Mr. Moore here in this paper he presents to-morrow on "Chemical Engineering Aspect of Renovating a Sulphite Mill" throws some light on how to handle that particular problem. We will hear this paper at the Canoe Club to-morrow evening.

DR. SAMUEL P. SADTLER: I might say too what both of these gentlemen said, that there is a very serious problem before one of the industries of the country in this matter of contending with the anthrax infection. The tanneries of the country, as represented by the heavy leather association and the morocco manufacturers association, are both of them now in close touch with the Bureau of Animal Industry at Washington over just this problem. When the Bureau of Animal Industry took the matter up first of all, they prescribed offhand that all hides and skins should be disinfected on

coming into the country by a forty-eight hour treatment of mercuric chloride. If that had been carried out literally, it would have run up the price of mercuric chloride and mercury compounds enormously. Beside that, while the heavy skins can stand mercuric chloride for the time prescribed as a disinfectant, the goat skins and light skins which are used for upper leathers would have been utterly ruined, all of the body of them being taken out by such a drastic treatment. Therefore the whole matter had to be taken up and studied with a view to finding whether there were not other conditions under which they could contend successfully with the anthrax danger. Prof. Jackson of the Columbia University Chemical Department has been acting for the heavy leather men, and I believe at Ballston Spa, New York, they have been operating very successfully with the chlorine treatment, perhaps not so entirely successful as they would have liked to have done, because of the points that were mentioned by Dr. Mason, that you may use up a great deal of chlorine before you kill the anthrax, by reason of the organic matter. A corresponding work with the morocco manufacturers is being handled more particularly by a coöperation between the chemists and bacteriologists of the Bureau of Animal Industry, and my firm—that is, my son who is most active in the matter, has been down to Washington a great many times and has been conducting a great many experiments, and they are studying the chlorine treatment under varying conditions and are studying sterilization by heat for the effluent liquors under certain conditions. They practically left out of the question the matter of sedimentation, for the reason that is probably known to many of us, that the average tanner, more particularly the morocco manufacturer, is sometimes located not in a specially desirable location where he has abundant room for sedimentation and that kind of thing, but is right in a built-up section of the manufacturing part of the city, where he has all kinds of difficulties to contend with as to his water supply and taking away of the waste waters; he has no room whatever, he is all built in, and for him to provide the large area necessary for carrying out anything like sedimentation would be a practical impossibility. Therefore they are at present leaving that out of the question, considering only chlorine treatment and heat sterilization. What they have to deal with is the wash waters and effluents from the washing or drum liquors as they are called. There are also secondary wash waters and then

they also have to deal with the case where, after unhairing, the hair is washed and prepared for the market. The great majority of the tanners sell the hair in the wet state without any preparation of their own; it goes to men who handle it, so that many of them don't have that to deal with. But the amount of water which a morocco manufacturer uses is something enormous and unbelievable almost. The amount of water that they use for their washing and so-called drum liquors runs into thousands and thousands of gallons daily, and all of that has to be treated for anthrax danger. The danger is a real one. There have been a number of cases of fatal results from anthrax in several of the tanneries beside the danger of the passing out of this effluent water which is contaminated, and most of them now have a daily visit from physicians to look over their operatives and to take hold of the first appearance of anthrax. It is active in this country, and it is a danger that they do not minimize. They are, therefore, coöperating very cordially with the Bureau of Animal Industry in trying to find a solution of this difficulty. They are not fighting the regulations at all because they realize it is a danger to themselves and their operators.

I merely mentioned this because I was interested in hearing what was said about this matter, and I am in touch at the present time with a part of what is being done on it.

Mr. JOHN V. N. DORR: Mr. Chairman, speaking of tannery wastes, there is a tannery in Pennsylvania now experimenting with sedimentation by continuous settling and they are operating now a test plant which is handling approximately 1-30th of the total flow of wastes from the tannery. This plant has been in operation on this scale since the middle of April, 1917, and the results have been fully as good as those obtained in the small scale experiments which were carried on for several months prior to its installation. These results show that by continuous settling in a basin of proper size with continuous sludge removal, an overflow may be produced which can be discharged in the stream and which will meet the state's requirements.

This tannery is one of the largest sole leather tanneries in this country and our estimates show that the total flow of wastes will be approximately 1,500,000 gallons per 24 hours. Our tests show that to handle this flow an area equal to two 100 ft. diameter circles would be required.

The thick product settling in the experimental plant is now being drained and then incinerated—apparently without much trouble, and without any additional fuel. This is being done to get rid of the anthrax germs. The practically clear liquor overflowing from the settling tank is being run into a meadow and drained away. The soil is sandy and porous. It is expected that in time the surface soil will be clogged due to further sedimentation of organic matter and precipitation of carbonates. The plan is then to use this land for a shallow aeration pool. Although the results of the experimental work are not conclusive, it appears very probable that it will furnish means for getting rid of this particular overflow.

It is interesting to note that by continuous settling 90% of the suspended solids and 30% of the dissolving solids are removed. This is a higher removal than is being obtained, to our knowledge, at any plant using intermittent settling tanks. It may be accounted for by the removal of the sludge at frequent intervals before it has time to decompose in the basin. Where decomposition is allowed to take place in the basin, gas bubbles rising through the liquor interfere with the settling of fresh entering wastes, and masses of sludge are buoyed up and float off in the effluent.

The plant—like a great many other plants in Pennsylvania—is under indictment for not disposing of its wastes, and a number of the other plants there are watching this work and have intimated that they may use this method of getting rid of the trouble.

Mr. WILLIAM P. MASON: Mr. Chairman, I should like to ask if any assistance is given the anthrax organism to sink, because the organism is a light affair and unless coagulated in some measure would sink but slowly. If it should be poured out in a fairly clean liquid upon ground which is afterward pastured over by stock, the earth worms would be very likely to carry the organism up to the surface and cause anthrax to spread among the cattle.

Mr. JOHN V. N. DORR: I have not heard anything about that particular feature of it and I am not in as close touch with it as I might be, but I do know that they are planning to burn the residue that settles and can treat the overflow with chlorine if necessary to kill anthrax.

The clarity of the overflow averages 160 parts of suspended solids per million. The overflow is alkaline, with its alkalinity all due to bicarbonates.

The overflow would go continuously to the same settling pond which when clogged eventually will be used as an aeration pond.

Prof. JAMES R. WITHROW: I unfortunately did not hear the paper and naturally cannot discuss it, but some of this discussion calls to my attention a matter that I became interested in some months ago, and as we have a number of notable experts on water and sewage here, I would like to ask them a question in this connection. I happened to be doing some work at a plant, a wood distillation plant, and while there, they called my attention to the fact that they were threatened with litigation because they were supposed to be contaminating the source of supply of water to a small town, and asked me to taste the water and see if I thought in my opinion the material that would come from that plant might be accused of giving the peculiar taste to the water. I tasted it and it certainly tasted like wood creosote, and I would have thought that undoubtedly it came from that particular plant had it not been that one or two things came to my attention by way of memory. They had told me that whenever the town water-company, ceased passing chlorine into the water there was no such taste, but every time they applied chlorine again the taste materialized. Then I remembered that in Columbus, Ohio, where I had lived for some time, we had exactly the same conundrum, and the city newspapers blamed the water works chemists for using too much chlorine. They said, and even the university professors, a number of them whom I had heard express an opinion, said the taste was due to chlorine. To me it always tasted like wood creosote, a carbolic or iodoform-like taste. I have been more or less familiar with these substances, but it happens there is no wood distillation plant in the State of Ohio. I saw at once here was a plant that could undoubtedly give that taste to a stream, yet here was a large city that the whole water supply was giving that taste and yet no such material was ever made in that state as wood distillation products, so the natural inference was that perhaps organic matter in the spring of the year, material which had remained in the ground all winter, extract of leaves and such things as that might have this taste and be changed or magnified in some way by this chlorine solution we were using—liquid chlorine in this Columbus plant. This matter is undoubtedly very well known to these water men, and I would like to ask a question of them whether it has been definitely settled that such apparent creosote tastes may arise in water sup-

plies of this kind in a perfectly normal way from normal organic matter in the water which has been treated with chlorine?

Mr. H. P. EDDY: Mr. Chairman, that is a very interesting question from two points of view. There is no doubt that under certain conditions we get a decided taste from the chlorine applied to our water supply. As a rule, however, that taste is less or less likely to be observed when the water contains the organic matter from the leaves and vegetation than when it is exceedingly pure, as is usually the case in the water from the Great Lakes, with which much trouble has been experienced. The second point is that the taste to which the gentleman referred, I should judge, is very similar to that which is imparted to water by the process used for quenching coke as it is drawn from the ovens. Large quantities of water are used for that purpose and run into the Lakes, for instance, and of course enormously diluted with the Lake water, and yet at times the taste in the Lake water drawn from some distance away from the outlet may be decidedly that of phenol. In one case that I have been connected with we have experimented by aerating water for the liberation of those tastes with more or less success. I am not prepared to say that it is absolutely successful, although it gives some promise of being at least helpful.

Dr. WILLIAM P. MASON: May I add that this question of taste is a deceptive matter. I do not know of a better instance to quote than that fishy taste which you often taste in the absence of fish. The people of Elmira tasted alum in the public water. They knew the chemical was to be put in the water throughout a certain territory, but the odd thing was they tasted that alum four days before it was put in—a real prophetic taste. You cannot always depend on taste.

Dr. EDWARD BARTOW: Mr. Chairman, along that line, a lady's hair in Illinois was bleached by the bleaching powder two weeks before it arrived—in the city supply.

What I got up to speak about was the experience on the Mississippi River. Generally in the spring, with the melting snow and the dilution of the water they have this taste, and it is to my mind rather doubtful whether it is the action of the bleaching powder on the organic matter or the change from rather hard water to the soft water which those who drink the water imagine is the bleaching powder taste.

Prof. JAMES R. WITHROW: I am glad to bring out this discus-

sion. I have heard most of the stories of this kind a great many times, illustrating the opinions which the gentlemen wish to emphasize, but being a chemist I was very inquisitive and I do not think biased in the ways mentioned. Undoubtedly in the City of Columbus we used to have and we do not have now for very good chemical reasons any such bad taste in the water. It is not a matter at all of soft water. We had at one time the largest water softening plant in the world and that water was soft, with a given degree of hardness and, of course, for long periods of time when it had no such taste, so of course it could not be blamed on the softness or the change from hard to soft, because we have had this soft water now for eight or ten years, so it could not be due to that. It could not be due to coke quenching because there are no coke manufacturing plants at all on that river system anywhere and no industries of any kind to any extent whatever, practically no factories, or almost none, along the whole Sciota River, and the whole thing is pretty well protected in that way. All I know about it is that at certain seasons of the year, particularly after the melting of snows, this taste always developed, and of course the people in the city said it was due to chlorine, for the reasons that have been mentioned here a little while ago. I never could see the chlorine in it; that is my own notion from tasting it myself; I thought it was this creosote taste. In fact, it was identical with what happened in this other case where the plant could have been blamed for it very justly. That is why it interested me. Many chemists would have said at once that as far as the taste was concerned that plant was undoubtedly to blame, but I could not help but remember our own case in Columbus where absolutely no such situation existed, and we could have ridiculously blamed our water works for exactly the same thing. That is, it was being contaminated by effluent from a wood distillation plant, whereas there was none in existence at all. So that there must be something which chlorine does that gives the taste, which is not at all imaginary, and while it may be very well known to the water chemists present, it may not be to others, it can easily be eliminated entirely. In fact, since I ran across this instance I watched our Columbus water very closely so as to see if I could find out the cause of it myself, but I never could detect any of that taste at all, and our water works chemist, Mr. Hoover, who is known to some here, I found, uses the system of cutting the chlorine down at

certain times when he has reason to suspect that more of this material is being brought down which gives the taste than at other times. Whether he is right in his theory or not, he cuts out the use of chlorine altogether at those times and he has no taste. Of course, no chlorine, no taste—that he found in his experience to be fundamental. He purifies the water at these times by the increase of lime, which cuts out the carbon dioxide by lime alkalinity, and under the system we have this causes the bacteria which are brought down to die. He increases the calcium hydroxide and cuts out the chlorine altogether, and there is no taste. I have noticed that for two years. There are times in the Sciota River Valley when the water brings down something which chlorine can act on, or at least simultaneous with the introduction of chlorine it greatly magnifies the taste and brings out the decidedly peculiar taste which is to me a phenol or creosote one.

Mr. HINCKLEY: I think some of the chlorine men ought to be heard from. Dr. Snowden is here and would like to be heard on it, only he is too bashful to get up.

Dr. SNOWDEN: I do not like to butt in on this discussion because I do not happen to be a member of this Society, but on account of a certain amount of interest that has been shown, I feel I must speak. I have had a chance to observe pretty closely the water coming from two filtration plants. In one case we have at our house the water from one of the plants and at the factory we have the water coming from the other one. The supply of water which comes to my house is treated with chlorine; the supply which comes from the other plant to our factory is treated with bleaching powder or calcium hypochloride. At certain times of the year, probably in the spring and in the fall, although I cannot say so definitely about that, but I have noticed that the water at our house has very often shown a very strong taste such as the gentleman who preceded me has described. In fact, Mrs. Snowden has very strenuously remarked about it and said that we must be getting rotten water. At the same time and with full knowledge of what was going on, I have drunk the water at the plant and do it all the time, simply to compare the two sources of supply, and I have never yet to my knowledge in all the time that the filtration has been using calcium hypochlorine, has been in operation, found any evidence at all of any taste. So I rather came to the conclusion that the treatment with chlorine does react, or that the chlorine

does react on the organic matter which may be contained in the water, probably vegetable matter, to give you chloride compounds—haven't any idea what they are, but which do have this peculiar and unmistakable taste. The taste is there—there is no question about it. The water comes from the same place in the case of the two plants. It is quite well known, I think, that calcium hypochloride does not act to chlorinate anything, it is a straight oxidizing agent, and chlorine is an oxidizing agent also, but it will act in cases of this kind without question in my mind at all to chlorinate some of these organic things.

Dr. F. W. FRERICHS: In connection with this matter of taste I recollect one paper which was reported in the New York reports of the International Congress of Chemistry two years ago. The paper was written by a Japanese who attempted to give us the standard of taste. He described minutely how the mouth must be prepared in order to taste accurately, and then he gives a standard solution equal to a normal solution which can be applied in ascertaining the degree of taste. Perhaps it might interest one of the gentlemen to read this article. I was one of the committee having to pass upon these papers and was present.

Mr. CHARLES T. BRAGG: I remember a paper read by Jennings of the Chicago Union Stock Yards last winter. Jennings had the job of helping to purify at the 39th street bureau in Chicago so that the water could be fed to the cattle in the stock yards, and I think at this time had entire charge of that plant. He read a very interesting paper in Detroit and particularly dwelt on the subject of calcium hypochloride in the treatment of water. I happened to be chairman of the reception committee that night and I was at the hotel with Jennings and one of the other boys, and I asked him what he knew about this taste question, because at that particular time we were all tasting chlorine in the water, whether they put it in or not, and he said then that he had never noticed any taste in the water at all with the use of calcium hypochlorite, but imagined he did taste it at times with the use of liquid chlorine. In view of the fact that he was quite an expert on hypochlorite and did not get that taste, I thought I might mention it.

Mr. ARTHUR B. CONNOR: In the City of Detroit when we first started in using calcium hypochloride shortly afterward there were numerous complaints about the taste of the water. It happens to be a fact that the Canadian Alkali Company operates an electro-

lytic chlorine and caustic plant across the river from the west portion of the city, and whenever the wind was in the right direction the entire population in the west side of the city complained about the chlorine in the water. Since the introduction of liquid chlorine, superseding the use of bleaching powder I have heard very few complaints about the taste of chlorine in the water; in fact, I doubt very much if there is any chlorine taste in the water at all at the present time where liquid chlorine is being used. Of course, that is Lake water.

Prof. JAMES R. WITHROW: I think it is only fair to state that at the time, I made a very serious effort to see whether chlorine could give such a taste as I have described and I made up chlorine solutions in water of all kinds, all dilutions, and used up my own taster in trying to discover such a taste as this creosote taste and could not find it. I went out in the woods and got water that had been standing around all winter in the woods and other places and chlorinated it, but I could not synchronize the taste, no matter what I did. When I took this water in this particular river, there was no question about the taste, and when I took the Sciota River water in certain times in the past I got the taste, although I was not able at this particular time to get the water from that particular river.

H. P. EDDY (Closure): It is gratifying to note the general interest which the discussion of this paper shows to exist in the subject of industrial wastes disposal. Two of the most perplexing problems, such as coping with the anthrax bacillus and its spores, and the treatment of sulphite liquors, were brought out by Dr. Mason. There is some encouragement that the former is in a way to be solved, by the use of chlorine, as mentioned by Dr. Sadtler. The experiments thus far made public, however, do not appear to be conclusive. It is to be hoped that this work can be carried forward in a most thorough and comprehensive manner, that the efficacy of this treatment under practical operating conditions may be ascertained at an early date.

The author has not had an opportunity to investigate the treatment of sulphite liquors, and therefore is obliged to plead ignorance as to the best means to be adopted with this particular class of wastes. He is convinced, however, that even this material can be successfully dealt with if a clear understanding is acquired of the scientific principles involved in the production of the conditions

which cause the trouble and in the processes available for the treatment of the wastes.

Mr. Dorr has brought to the attention of the Institute an interesting example of the treatment of tannery wastes, particularly with a view to the destruction of the anthrax organisms. If it is going to be necessary to actually incinerate all of the wastes which may contain the anthrax germ, the disposal of tannery wastes is certain to be a serious burden upon the manufacturer. Yet it is difficult to see how these organisms can be destroyed except by disinfection or by incineration. Care must be taken not to adopt treatment methods which will result in spreading infection rather than in preventing it.

The discussion of the taste found in chemically disinfected waters, shows how diversified opinions are upon this subject, and the difficulties encountered in the solution of this problem. Unfortunately there appears to be no detrimental physiological effect of the disinfection, and time can be afforded for the discovery of means of preventing the conditions which are objectionable from the esthetic point of view. If the cause can be ascertained, a long step in advance will have been taken.

THE TREATMENT OF SEWAGE BY AERATION IN THE PRESENCE OF ACTIVATED SLUDGE—III

By EDWARD BARTOW

Read at the Buffalo Meeting, June 20, 1917

In previous papers read at the San Francisco¹ and Cleveland meetings, experimental work with activated sludge was described with special reference to the work done in the sewage experiment station of the Illinois State Water Survey at the University of Illinois. The removal of ammonia and the development of nitrate nitrogen have been described. The process has been shown to be essentially bacteriological. By analyses of the sludge and by pot cultures of wheat, the sludge has been shown to be valuable as a fertilizer. Experiments in concrete tanks operating on the fill-and-draw plan have shown that sludge can be built up rapidly without seeding from other sludges. During the building-up process the increase of the nitrogen and phosphorus content of the sludge is very rapid. The necessity for oxygen has been shown by the increase of carbon dioxide, and decrease of oxygen in the effluent air. Since the last paper was prepared a large amount of experimental work has been done in many places in this country and in England. It would be impossible in a paper of limited extent, to describe or even mention all of the work. We will therefore confine ourselves almost entirely to the work done at the State Water Survey sewage experimental station at the University of Illinois.

CONSTRUCTION AND OPERATION OF CONTINUOUS-FLOW PLANT

The continuous-flow plant which had just been put in operation at the time of the Cleveland meeting was expected to handle 200,000 gallons of sewage and sludge per day, and was built in a septic tank designed by Professor A. N. Talbot, in 1897, for the city of

¹ Transactions 8, 119-31 (1915). 9, 161-8 (1916).

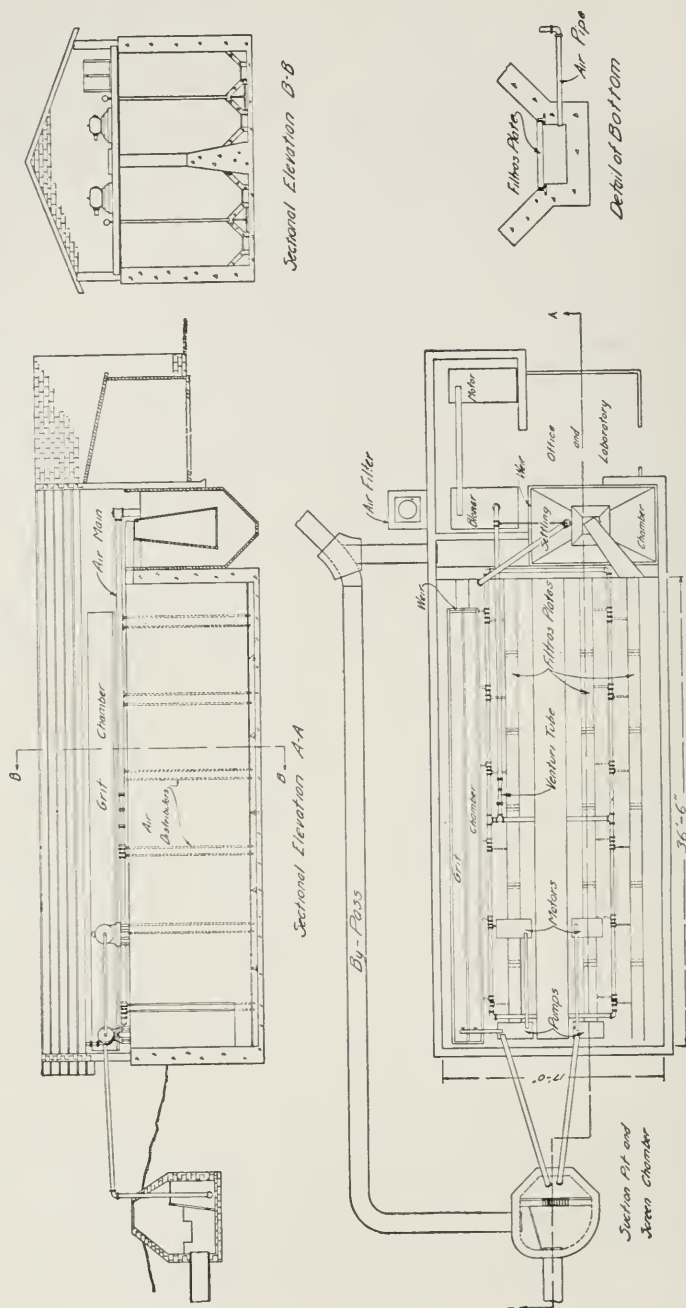
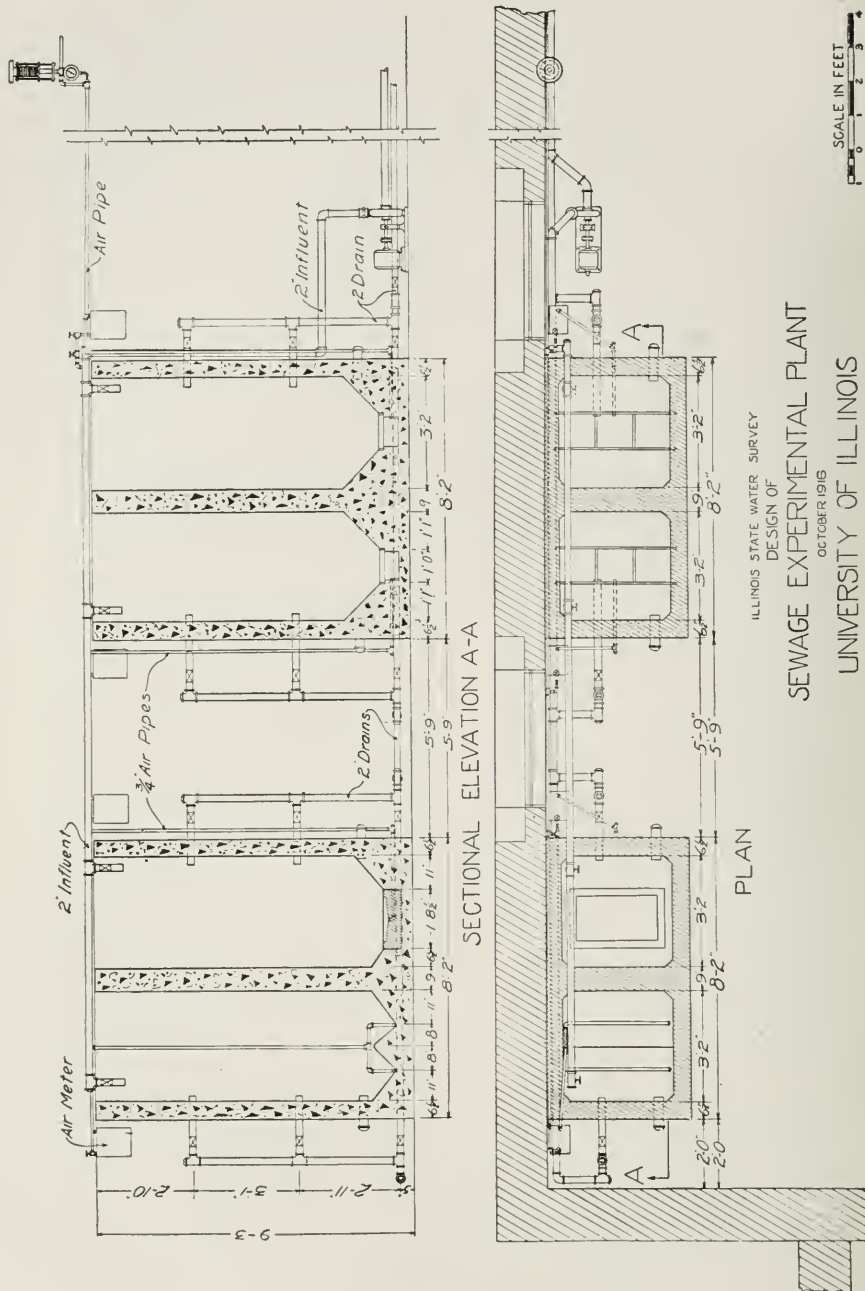


FIG. 1.—Illinois State Water Survey Sewage Experiment Station

Champaign. The tank was reconstructed for the activated sludge process. The plant contains a screen chamber and pumping pit, a grit chamber, an aerating chamber, a settling chamber, a blower room and a laboratory containing sludge-drying apparatus (see Fig. 1). A sludge-drying bed and a pond into which the effluent from the process may be discharged, are also provided. The sewage is drawn from the main outlet sewer from the city of Champaign. The daily flow is estimated to be from 1,000,000 to 1,500,000 gallons of sewage, though in wet weather, owing to seepage into the sewers, the amount of flow is greatly increased. The manhole nearest the septic tank was modified to serve as a screen chamber and suction pit for the pumps.

A screen with vertical bars spaced with $\frac{3}{4}$ -inch openings prevents coarse material from reaching the pumps. A grit chamber 34 ft. long with two compartments, each 1 ft. wide, was provided to catch the heavy material. This was later discarded owing to modifications in the plant which will be described later. The sewage flows from the grit chamber into the aeration chamber, a rectangular concrete tank 17 by $36\frac{1}{2}$ ft. in plan and $9\frac{1}{2}$ ft. deep. A greater depth would have been desirable, but using an old tank, it was impossible easily to obtain it. The aerating chamber after allowances are made for baffling, and sloping bottom has a capacity of 36,000 gallons. It is divided longitudinally by three baffles into four compartments through which the sewage flows a distance of about 140 feet. The lower part of each compartment has sides sloping towards the central part to a channel $11\frac{1}{2}$ in. wide and 4 in. deep, and extending the length of the compartment. Above the channel, Filtros plates are supported on T-bars embedded in concrete. The channel below the Filtros plates was divided into sections for six Filtros plates each, with the expectation that each set of plates would be separated from all the others and that the supply of air to each set could be regulated by an air pipe and valve. It was, however, found impossible to regulate independently the air for each set of plates. The aeration chamber was calculated to treat 144,000 gallons of sewage and sludge daily, if aerated during a period of six hours, 170,000 gallons if aerated five hours, and 216,000 gallons if aerated four hours. From 70,000 to 85,000 gallons of sludge were pumped back into the aeration chamber, for each 100,000 gallons of sewage added. The calculation for the capacity of the chamber was, therefore, reasonably accurate. From



ILLINOIS STATE WATER SURVEY

DESIGN OF

SEWAGE EXPERIMENTAL PLANT

OCTOBER 1916

UNIVERSITY OF ILLINOIS

FIG. 2.

the aeration chamber, the mixed sewage and sludge passes to a settling chamber 6 by $10\frac{1}{2}$ ft. in plan and 11 ft. deep, at its lowest point, having a capacity of 3700 gallons. If the sewage and sludge flowed through all parts of the settling tank it would have a retention period of twenty-four, thirty-one, and thirty-seven minutes, with a flow through the aeration chamber of four, five, and six hours respectively. In order to assist the settling of the sludge the liquid passes down into the center and up around the edge of a hollow frustum of a pyramid and overflows into drains which entirely surround the settling chamber. From the settling chamber the effluent flows over a weir and is either returned to the sewer or discharged into a pond, formed by two dams thrown across the abandoned bed of a stream. This pond covers about one-tenth of an acre and has a maximum depth of 3 ft. The sludge is withdrawn from the settling chamber by an air lift and can be discharged at the place where the raw sewage enters into the aeration chamber or diverted for experimental purposes or discharged into the sewer. Air is supplied for aeration and for the air lift by a rotary positive pressure blower, having a rated capacity of 300 cu.ft. per minute, driven by a 15-horse-power electric motor. The air is filtered through cheesecloth spread over a box having sides of wire netting, and is measured through a Venturi meter.

The plant was operated from May 25 to June 11, 1916, when it was shut down to repair leaks due to faulty concrete work. Much care should be taken in order to make the concrete air-tight, or cast-iron or metal frames as used at Milwaukee and Cleveland should be used. The plant was again put in operation on July 11, and operated continuously until October 22. The amount of sewage added during weekly periods varied from 61,000 to 177,600 gallons per day. Approximately 2 cu.ft. of air per gallon of sewage was necessary to obtain stable effluents. Undoubtedly better results could be obtained with an increased settling tank capacity, and a steeper slope from the vertical sides to the extreme bottom of the chamber. The actual period of flow through the settling tank as determined by tests with fluorescein and with salt when the rate of pumping was 133,900 gallons per day, was found to be twenty minutes instead of thirty-four minutes, as calculated. A larger chamber or two chambers, possibly, with an arrangement for aeration between them would undoubtedly increase the capacity of the plant.

For further experiments the plant was modified by cutting out the grit chamber and inserting a short box, into which the sewage was pumped. The box is 4 ft. 9 in. by 11 in. in plan and 10 in. deep and has a V-shaped weir at the end for measuring the sewage. One-quarter of the aeration chamber was cut off from the remainder for a sludge aerating tank. This decreased the length of flow in the aeration chamber to 105 ft. The plant was again started January 17, 1917, and has been in operation continuously until the present time, June 20, 1917.

COMPARISON OF METHODS OF AIR DIFFUSION

An important feature of the activated-sludge process is the method of air diffusion. In the original experiments air was introduced into the sewage in bottles through small glass tubes. The relatively large bubbles delivered by this method made it appear feasible, that better air diffusion to break up the air stream into smaller bubbles might be productive of increased efficiency, and thus become an important feature in reducing the cost of the process. In the first continuous-system experiments conducted at Manchester by Ardern and Lockett,¹ a series of perforated pipes placed at 4-inch intervals and fixed at a depth of 12 in. below the surface was used. In subsequent experiments Ardern and Lockett used porous tile similar to those used by Fowler and Mumford in connection with other work on the clarification of sewage by means of specific organisms. Ardern and Lockett reported that a comparison of the results with those obtained with pipe diffusers showed advantages in favor of porous tile. This was demonstrated in three sets of experiments using (1) an excessive amount of air on a strong sewage, (2) an average amount of air on a dilute sewage, and (3) a minimum amount of air on a dilute sewage. At Salford² a roughing filter was converted into an activated-sludge tank and the air pipes of the filter were used for diffusers. The outlets one inch in diameter were placed 8 in. apart on the top and sides of the pipes. Effluents within the requirements of local conditions were obtained. Fowler³ described an arrangement devised originally by Jones and Atwood, which consists of a series of nozzles, one in

¹ J. Soc. Chem. Ind., **33**, 523-39, 1122-4 (1914).

² Surveyor, **46**, 681-2 (1914); J. Soc. Chem. Ind., **33**, 1124-30 (1914).

³ J. Inst. San. Engrs., March and April, 1916.

each square yard of the aeration tank. The scheme was not satisfactory because deposits of sludge formed around each nozzle. In this country, Filtros plates were first used for air diffusion in a small tank in the laboratory of the Illinois State Water Survey, and have since been used rather generally in America. Much has been written and various opinions expressed regarding kinds of air diffusers. Mr. George T. Hammond¹ in April, 1916, after visiting five working plants, stated that air distribution troubles had been rather general and that he believed that pipe grids were more satisfactory than porous diffusers. Hammond states that the use of porous diffusers has been largely from theoretical rather than practical reasons.

Hatton² after various experiments, reports that Filtros plates were the most satisfactory medium he has found for air diffusion, but that they should be of uniform porosity, should be properly installed, and all oil and dust should be excluded from the air passing through them. Wooden-block diffusers give good diffusion with least frictional loss. The bubbles are smaller than those obtained by Filtros plates. The experiments, however, are insufficient to warrant their adoption for working-scale installations. Furthermore, the deterioration is apparently rapid.

Pearse and Richardson,³ in a recent report on the activated-sludge process for handling Packingtown trade waste, state, "At the present time Filtros plates offer the most satisfactory air distribution. Although the cost of maintenance may be somewhat higher than the perforated-pipe grids, we believe the distribution is better and the size of air bubbles is much smaller with consequent increase of efficiency. The basswood plates, now being tested in Milwaukee, produce a remarkably fine air bubble, insuring a considerable reduction in the use of air. The life of basswood plates is at present very uncertain because of possible decay."

The statements by various authorities concerning the use of diffusers were so decidedly at variance that we were led to make some comparisons of different diffusers in service under identical conditions. The four reinforced concrete tanks used in former experiments and described in a previous report,⁴ were remodelled

¹ *Eng. News*, 75, 798-801 (1916).

² *Eng. and Contr.*, 45, 104-8 (1916).

³ Report of Pearse and Richardson, The Activated Sludge Process for Handling Packingtown Trade Wastes. Sanitary District of Chicago, 1917.

⁴ Transactions, 9, 161-8 (1916).

and each fitted with a different air diffuser (see Fig. 2). The tanks operate on the fill-and-draw system and are 3 ft. 2 in. square and 8 ft. deep. At each filling 350 gallons of sewage were added.

One tank (A) was fitted with a system of perforated pipes having perforations $\frac{1}{8}$ of an inch in diameter placed 2 in. apart and staggered at an angle of 45° from the top of the pipes. There were about 40 holes in the pipes or 4 to each square foot of surface area. The bottom of the tank is sloped from the center and sides at an angle of 45° , thus forming two V-shaped channels of equal size, 1 ft. in depth, running entirely across the tank.

The bottom of the second tank (B) was hopped from all four sides and a concrete container for wooden-block air diffusers was placed in the bottom of the hopper. The container was patterned after one designed by Nordell¹ and used at Milwaukee in the Nordell aerating tank. The container is a one-piece casting 2 ft. 8 in. long, 1 ft. $8\frac{9}{16}$ in. broad, and 5 in. thick with a receptacle for the blocks 1 ft. $3\frac{9}{16}$ in. by 2 ft. 3 in. in plan, $\frac{3}{4}$ of an inch deep at the edge, and $1\frac{1}{4}$ in. deep at the center. The wooden blocks rest upon a series of thirteen ridges, $\frac{1}{2}$ in. wide and $\frac{1}{4}$ in. high that run across the receptacle, leaving a $\frac{1}{4}$ -in. space underneath for the air to circulate. The surface of the container was cast on a curve so that the tendency of the wooden blocks on swelling would be to wedge themselves more firmly into position. The basswood blocks used in our experiments were very kindly furnished us by T. Chalkley Hatton. They were $\frac{1}{2}$ in. thick, 6 in. long, and $2\frac{1}{8}$ in. wide. At first difficulty was experienced in keeping the blocks in position, because of the excessive swelling that took place when they were placed under water and also because they became soft and spongy. Many of the blocks became so curved and twisted that they were discarded. It was found necessary to place strips of heavy galvanized iron on edge between each row of blocks for reinforcement and to close up certain joints with oakum.

Filtros plates of different porosity, kindly furnished by the General Filtration Co., were placed in two of the tanks (C and D). Three plates were used in each tank, covering one-third of the area and forming the bottom of a trough with sides sloping at an angle of 45° . The plates of the third tank (C) were marked "fine" because on the basis of dry rating these plates passed 5.8 cu. ft. of air per minute per square foot under a water pressure of 2 in.

¹ Annual Report of Sewerage Commission of Milwaukee (1916).

When saturated with water and passing 2 cu. ft. of air per minute they showed a resistance on a water gauge of 11.4 to 11.8 in. The fourth tank (*D*) was equipped with plates marked "coarse" which on the same basis passed 12 cu. ft. of air per minute per square foot. When passing 2 cu. ft. of air per minute these plates registered a resistance of 8.8 to 9.6 in. of water pressure.

The tanks were operated during three periods of fifteen, twenty, and thirty-five days, respectively. Each of the tanks was operated in three aeration periods daily of 510, 300 and 270 minutes with a two-hour allowance between the periods for settling, emptying, and filling. The same amount of air as measured by ordinary gas meters was added to each tank. All conditions were maintained as nearly identical as possible. The sewage was pumped from the main sewer just outside the city limits of Champaign, and accordingly was fresh. It was a fairly strong, domestic sewage with no trade wastes. No activated sludge was added to the tanks at the beginning of any of the series of tests.

Samples of sewage were taken as the sewage was being pumped into the tanks and samples of effluents were collected at the close of each aeration period after the sludge had been allowed to settle for thirty minutes. The methods of analysis were those given in the 1917 edition of *Standard Methods for the Examination of Water and Sewage* of the American Public Health Association.

In the first series of tests only the perforated pipes and Filtros plates were used. The series continued only fifteen days. The average purification, measured in terms of removal of turbidity, removal of oxygen-consuming capacity, and the production of nitrate nitrogen was greatest in the tanks with the coarser Filtros plates, next in the tank with finer plates and least in the tank with perforated pipes. Measured in terms of reduction of ammonia nitrogen and sludge accumulation the order was reversed. About 19,000 gal. were treated with 2.5 cu. ft. of free air per gallon.

All four tanks were in operation in the second series of tests, which continued twenty days. Measured in terms of removal of turbidity, removal of oxygen-consuming capacity, production of nitrate nitrogen, and sludge accumulation, the tanks containing Filtros plates gave the best results, The tank with the wooden blocks was next and the tank with perforated pipes the poorest. Measured in terms of reduction of ammonia nitrogen, the tank

with the perforated pipes was the best. About 17,000 gal. of sewage were treated with 1.8 cu. ft. of free air per gallon.

The third series of tests, which lasted thirty-five days, was the most satisfactory. (See Tables 1 and 2.) There was no sludge present at the beginning and owing to the length of the test at times some of the excess of the accumulated sludge was wasted. No accurate comparison of the sludge accumulation at the end of the series can be made. The maximum amount of sludge was reached last in the tank with perforated pipes. Removal of turbidity and oxygen-consuming capacity was practically the same in all tanks. Measured in terms of removal of ammonia nitrogen and in production of nitrate nitrogen the tanks with Filtros plates were decidedly superior. Ammonia nitrogen was entirely removed in the tanks with Filtros plates after seventeen days. Owing to rains, nitrate nitrogen was present in the raw sewage during the early part of the series and continued to increase in the tanks containing Filtros plates, reaching about 25 parts per million. Practically all of the nitrate nitrogen disappeared from the other tanks. The poor results from the tank with wooden blocks were probably caused by the development of a hole in the tank which prevented the formation of finely divided bubbles. The stability to methylene blue was tested on and after the eleventh day and all effluents from the tanks containing Filtros plates were stable for ten days at 20° C. Most of the effluents from the other tanks were unstable. Nearly 30,000 gal. of sewage were treated in each tank with 3.2 cu. ft. of free air per gallon. The sludges in the tanks with Filtros plates settled better and, after removal at the end of the series, had specific gravities of 1.013 and 1.022 compared with 1.006 for the sludges from the other tanks.

The results obtained from these comparative tests indicate the superiority of Filtros plates as air diffusers over perforated pipes, such as were used in our tests under the conditions maintained. The wooden blocks were difficult to handle, though this was caused in part by the faulty design of our containers. Even in the time they were used there was evidence of considerable deterioration. From the results obtained we could distinguish little, if any, difference between the coarse and fine grades of Filtros plates. With air free from dust and oil there should be little trouble experienced from clogging of plates.

TABLE I
SUMMARY OF RESULTS OBTAINED IN THE COMPARISON OF EFFICIENCY OF METHODS OF AERATION
MEASURED IN TERMS OF AMMONIA NITROGEN, NITRATE AND NITRITE NITROGEN, AND OXYGEN
CONSUMED
(Parts per million)

Period. 1917.	AMMONIA NITROGEN.				NITRATE AND NITRITE NITROGEN.				OXYGEN CONSUMED.						
	Sewage.	Effluents.				Sewage.	Effluents.				Sewage.	Effluents.			
		A	B	C	D		A	B	C	D		A	B	C	D
Mar. 27-Apr. 1..	21	17	17	18	17	.9	1.2	4.0	3.9	3.9	58	26	19	20	22
Apr. 1-Apr. 6..	17	17	16	16	16	4.7	3.9	4.7	6.1	6.3	46	21	18	15	14
Apr. 6-Apr. 12..	16	11	9	8	9	5.1	4.9	4.5	5.9	7.2	50	26	24	19	26
Apr. 12-Apr. 17..	26	30	29	0	0	.3	.4	.3	6.8	10.2	55	32	26	25	16
Apr. 17-Apr. 22..	21	21	21	0	0	1.2	.3	.0	15.0	16.9					
Apr. 22-Apr. 27..	25	24	23	0	0	1.0	.2	.1	25.8	26.0					
Apr. 27-Apr. 30..	22	30	20	0	0	4.5	.3	.0	23.8	24.7					
Average.....	21	20	19	6	6	2.5	1.7	1.9	12.6	13.6	52	21	22	20	19
Reduction.....	....	5%	10%	71%	71%	....	....	....	....	....	....	60%	58%	62%	63%
Results April 12-30 after Activated Sludge was formed															
Average.....	24	24	23	0	0	1.7	.3	.1	17.8	19.4	55	32	26	25	16
Reduction.....	....	0%	4%	100%	100%	....	....	....	....	....	....	41%	53%	54%	70%

A = tank with perforated pipes; B = tank with wooden blocks; C = tank with fine Filtritos plates; D = tank with coarse Filtritos plates.

TABLE II

SUMMARY OF RESULTS OBTAINED IN THE COMPARISON OF EFFICIENCY OF METHODS OF AERATION MEASURED IN TERMS OF TURBIDITY AND THE ACCUMULATION OF SLUDGE

(Parts per million)

Period, 1917.	TURBIDITY.					PER CENT SLUDGE.			
	Sewage	Effluents.				Effluents.			
		A	B	C	D	A	B	C	D
Mar. 27-Apr. 1.....	282	48	39	46	46	9	8	8	7
Apr. 1-Apr. 6.....	317	9	6	6	6	14	14	12	12
Apr. 6-Apr. 12.....	190	9	5	5	5	18	21	18	18
Apr. 12-Apr. 17.....	248	7	5	5	5	26	29	25	28
Apr. 17-Apr. 22.....	306	5	5	5	5	29	35	34	31
Apr. 22-Apr. 27.....	309	5	5	5	5	38	37	44	39
Apr. 27-Apr. 30.....	268	5	5	5	5	35	33	36	33
Average.....	274	13	10	11	11				
Reduction.....		95%	96%	96%	96%				

Results April 12 to 30 after Activated Sludge was formed

Average.....	283	5	5	5	5	38	37	44	39
Reduction.....		98%	98%	98%	98%				

A = tank with perforated pipes; B = tank with wooden blocks; C = tank with fine Filtros plates; D = tank with coarse Filtros plates.

DEWATERING OF ACTIVATED SLUDGE

Satisfactory purification of sewage has been obtained by us and by many others, but before the method can be considered an unqualified success, a practical and economical method of drying the sludge must be found. Although drying on sand-beds had been tried at Cleveland, and we had ourselves tried it, we thought wise to repeat the experiments on better constructed beds than were used in our previous works. The experiments were not successful. Various methods have been tried by different investigators, but we have at the risk of duplication experimented with many of these methods. Owing to the large amount of moisture in the sludge, 98 and 99 per cent, the solid matter obtainable from a foot depth of sludge would be only from $\frac{1}{4}$ to $\frac{1}{2}$ an inch, according to the residual moisture content. It was also difficult to separate

the sludge and sand. The fertilizer obtained was more or less impure and of decreased value. The sand-beds used were $\frac{1}{100}$ of an acre in area and divided into five compartments. Underdrains were overlain with 10 in. of coarse gravel and 8 in. of sand. The beds were provided with a canvas cover supported on a frame work so that they could be protected during storms. One compartment was allowed to dry after a single filling, another after two fillings, another after three fillings. In no case did we feel that the results were sufficiently satisfactory to warrant the use of sand-beds for the drying of the sludge and the production of a commercial fertilizer.

Experiments with a filter press with leaves $8\frac{1}{2}$ in. square, operating on a fairly concentrated sludge were also unsatisfactory. It has thus far been impossible for us to obtain a cake of good consistency. Further experiments are to be tried with the hope that better results can be obtained.

Through the courtesy of the Koering Cyaniding Company, of Detroit, a rotary filter was placed at our disposal. This style of filter is used satisfactorily in filtering slimes in extracting gold and silver by the cyaniding process. The apparatus consists of a cylinder of Filtros plates supported on a perforated steel cylinder outside of which at a distance of about 1 in. is a solid steel outer shell. The material to be filtered is forced into the interior of the cylinder of Filtros plates, the cylinder is revolved and a cake of sludge is built up on the inside of the plates. The liquid filters through the plates into the space between the inner and outer shells. Air pressure can be exerted from the interior to dry the cake, and from the exterior to loosen it. The plates can be cleaned by back-flushing with water. The first trial with a comparatively heavy and not very fresh sludge did not give satisfactory results. The quick-opening door could not stand the pressure. Another trial will be given as soon as the door can be replaced.

Mohlman¹ reported experiments with two small centrifuges one of the low-speed basket type and the other of the high-speed bottle type. The basket of the low-speed machine was 8 in. in diameter and 6 in. deep. The periphery was perforated with numerous holes $\frac{1}{16}$ of an inch in diameter. When the holes were covered with a strip of muslin cloth, approximately 1 gal. of 98 per cent moisture sludge was put into the centrifuge and after

¹ Thesis. University of Illinois. June, 1916.

fifteen minutes, 700 grams of 91 per cent moisture sludge were obtained. The high-speed bottle-type machine reduced the moisture from 98 per cent to 92 per cent in three minutes. Mohlman stated that in order to be economical there should be an automatic arrangement for removing the cake. The most successful apparatus of this type is the Schafer-ter Meer centrifuge described by Hammond.¹ This machine is said to be very efficient but was too expensive for us to obtain for experimental work.

At Cleveland, Pratt and Gascoigne² used a laundry centrifuge with a 26-in. basket, lined with a $\frac{1}{4}$ -in. wire mesh inside of which was a canvas bag. In the best run, when the basket revolved about 1200 revolutions per minute, 60 gal. of 97 $\frac{1}{2}$ per cent moisture sludge was added in about twenty-five minutes and in two hours the moisture content was reduced to 84 per cent. The time required would seem to make this process impracticable.

Working on the assumption that the principle used in drying of china clays or that used in the cream separator might be applicable, a modified basket-type centrifuge and a modified cream separator were tried. The holes of the 8-in. basket-type centrifuge were covered with a strip of rubber packing. The best results were obtained with 1500 revolutions per minute, which was the limiting speed of the machine. This would seem to indicate that the process would give efficient results if carried on at an increased speed. and would yield an effluent suitable for returning with the sewage to the aeration chamber.

A second series of tests was made with a cream separator, the bowl of which was modified, by removing the inner disks and discharging the clarified liquid about an inch from the center of the bowl at the top. The sludge added at the top dropped to the bottom of the bowl, and the liquid was thrown out over the rim.

Sludge cake containing from 85 to 86 per cent of moisture was obtained by the cream separator in six to eight minutes, which encouraged us to obtain a special machine for further experiments.

A specially designed centrifuge was purchased from the Tolhurst Machine Works of Troy, New York. This machine is 12 in. in diameter, 9 $\frac{1}{2}$ in. high, and at a speed of 1800 exerts a centrifugal force of 550 lb. According to its concentration from 10 to 25 gal. of the sludge are added and 10 lb. of cake obtained. The sludge

¹ *Eng. News*, 75, 800 (1916).

² *Eng. News*, 76, 1124 (1916).

cakes contain about 88 per cent moisture. The space underneath the rim contains 0.153 cu. ft. Owing to the small size of the machine and to the fact that the material must be scraped out, the time of cleaning is longer than would be required for a larger machine with an opening in the bottom, so that a large machine could undoubtedly have been filled and emptied more rapidly than the small laboratory machine. We have found it entirely possible to fill and empty the small machine four times in one hour. Calculating that the same rate could be used with a 40-in. machine having 46 times the capacity, we could obtain in each filling 460 lb. of sludge of 88 per cent moisture, equivalent to 55 lb. of dry material. One 40-in. machine would, therefore, deliver the equivalent of 2200 lb. of dry material in a working day of ten hours. On the supposition that $\frac{1}{2}$ ton of dry material will be obtained from 1,000,000 gal. of sewage, one machine would dewater the sludge from 2,000,000 gal. of sewage per day. The cost of the 40-inch machine at present is only \$750 and the power to run it is small enough to make the process appear practical for preparing sludge cake for a dryer.

The actual cost of dewatering will depend upon the amount of water that can be removed by the centrifuge, the size of the dryer and the amount of coal required for removing the residual water. A drying test, using 220 lb. of 88 per cent sludge-cake, made by the John P. Devine Co., indicates that the dewatering process can be made practical.

The author desires to acknowledge his indebtedness to the members of the staff of the Illinois State Water Survey and especially to J. F. Schnelbach, F. L. Mickle, W. D. Hatfield, and E. Greenfield for their interest and assistance in carrying out the experimental work.

DISCUSSION

Dr. WILLIAM P. MASON: What does the effluent look like?

Dr. EDWARD BARTOW: The effluent from the plant, not the effluent from the centrifuge, has a turbidity of less than five parts, and from our plant is water white.

Dr. WILLIAM P. MASON: Has it ever been tried on industrial wastes, for instance, wastes like the red liquor from a sulphite pulp plant?

Dr. EDWARD BARTOW: Experiments on a small scale with the

sulphite liquor from a starch factory at Decatur, alone and mixed with domestic sewage, has shown the process to be satisfactory. At the stock yards, they have used the concentrated stock yard waste, but have to use about 4 cu. ft. of air per gallon of the sewage, and to aerate a longer period, about eight hours.

Dr. WILLIAM P. MASON: Then with reference to the starting of a new plant, how does it apply? Build one, let us suppose, and start it up to-morrow; about how long before the condition will be right for getting good results?

Dr. EDWARD BARTOW: On the second day there will probably be a removal of 75 per cent of the suspended matter, and, if everything goes well, in ten days the plant will be running normally.

Dr. WILLIAM P. MASON: Well, then, you do not have to send anywhere else to get sludge?

Dr. EDWARD BARTOW: No, sir.

Dr. WILLIAM P. MASON: The reason I ask, Fort had a plant down at South Brooklyn and he had been pumping air there for a long period and claimed he had not gotten any result, if my memory serves me, for three months; subsequently he got results. They were a long time coming.

Dr. EDWARD BARTOW: The plant in Brooklyn would be hardly fair for comparison. They had a very large tank filled and emptied through small pipes. They could only fill about once a day. In our work where we can fill and empty then fill and draw tanks in a few minutes, and where we use the continuous flow, we have no difficulty whatever in getting a very great improvement on the second day and in ten days we have been able to get a stable effluent and an activated sludge having from 5 to 6 per cent of nitrogen.

Dr. WILLIAM P. MASON: Then it is possible to over-blow the sewage?

Dr. EDWARD BARTOW: Yes, it is possible to over-blow the sludge, and also on the other hand if septic action takes place, it is a great hindrance to the process.

The SECRETARY: What proportion of the nitrogen of the sewage do you get in the sludge?

Dr. EDWARD BARTOW: I cannot answer that question accurately. The ammonia nitrogen usually goes off in the effluent as nitrate nitrogen, indicating that the nitrogen in the sludge has come from the nitrogen of the insoluble material of the sewage.

Dr. WILLIAM P. MASON: Suppose that a city is large and the

plant is situated a long distance from the outlying sewers and the sewage is decidedly septic, what can be done?

Dr. EDWARD BARTOW: The situation at Milwaukee explains that. At their plant they have sewage collected from all parts of the city, some of it having flowed through the sewers for miles so that it has become decidedly septic. Apparently as soon as the air is blown through that sewage the odors are blown away. Observers can stay above the tanks without the least inconvenience, and good purification is obtained.

Dr. WILLIAM P. MASON: And a water white effluent?

Dr. EDWARD BARTOW: Yes, a water white effluent. The color of the effluent would probably be in most cases less than 20 on the platinum scale. Even iron would be removed because of the aeration.

CHEMICAL ENGINEERING ASPECT OF RENOVATING A SULPHIDE MILL

By HUGH K. MOORE

Read at the Buffalo Meeting, June 20-22, 1917

IN the winter of 1909 and 1910 I was called to La Tuque, P. Q., Canada, in order to render what services I was able in renovating and reconstructing a pulp mill running on the so-called sulphate process. The word sulphate is a misnomer and I have always objected to the term, which even though accepted in the trade as descriptive of the process, really is not descriptive of the process by which the pulp is made. As you all know, the so-called sulphate process is so named from the large use of sulphate of soda as a raw material. This sulphate of soda, however, is not used directly in cooking as it is reduced beforehand to sodium sulphide, sodium hydrosulphide, caustic soda and carbonate of soda. The essential difference between this process and the soda process is the sulphide content of the cooking liquor. The name sulphide then is descriptive of this particular process of making pulp and is as correct as "soda" and "sulphite"; names which clearly designate the other well-known processes by which pulp is made.

Now I wish to say, lest you expect too much, that when I went to La Tuque I did not know what a sulphate mill was and understood nothing about the process; and furthermore I was called upon so suddenly that I had not time to inform myself as to the nature of the process before I started.

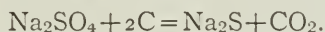
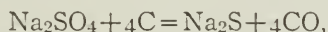
Before going into details as regards the processes and innovations a few remarks on the scope and limitations of this article may not be out of place. In the first place, this being about one particular mill instead of several mills, I purposely suppress all data on costs, maintenance, repairs, etc., neither shall I give any data as to yield per cord of wood, or salt cake, fuel, labor, repairs, etc., etc., per ton of pulp. Neither shall I give any figures on any of the installation costs. In stating the facts and methods of overcoming the

difficulties I want it to be particularly understood that I am not claiming credit for all the different changes made. Many of these I made, but many were made by Mr. Brown, Mr. Lovett and others, many were combinations of ideas of all, and it would puzzle a Philadelphia lawyer to assign to whom credit for certain of these changes should be given. The idea in mind is not to assign credit to any one person or group of persons but to show how a knotty problem was tackled and solved.

RÉSUMÉ OF SO-CALLED SULPHATE PROCESS

In order that those who have no more knowledge of the workings of the sulphide process than I had at the start (if there be any such) may have an understanding of the difficulties encountered I think I had better give a short résumé of what the sulphide process is. Woods of the conifer type are mechanically partitioned to form chips about $\frac{3}{4}$ of an inch square and $\frac{1}{8}$ of an inch thick through a chipper and these are run into a digester. After the digester has the required amount of chips the cooking liquid or alkali is run in, the digester is closed and heated by live steam, keeping the pressure on top of the digester during the cooking at 90-100 lbs., relieving the excess of liquor and steam which are separated in a separator and blowing the steam into water to heat it so that it can be used in washing the pulp. When the digester is cooked, it is connected with tanks and blown. The steam is blown off through vomit stacks, the liquor drained through false bottoms and the pulp washed according to the principles of systematic counter-current extraction. Now, owing to the propensities of this liquor for foaming the ordinary evaporator was not thought available so the liquor was passed through a disc evaporator, the source of heat being the waste gases from the steam boilers. The disc evaporator in brief is made of hundreds of pieces of iron plates set around a revolving shaft. As these discs revolve they dip into the liquor, then emerge from the liquor with a film of liquor thereon. The hot waste gases from boilers pass over these films evaporating the water. By having several of these in series and enough waste heat you can progressively concentrate the liquor. After passing through the disc evaporators heated by furnace gases the partially concentrated liquor passes another set of disc evaporators heated by gases from the incinerator. By this means it is possible to concentrate the liquor to 20° Bé,

where mechanical troubles place a limit to this method of concentration. From the disc evaporator it runs to an incinerator which is simply a brick-lined rotary furnace. The remainder of the liquor is evaporated and the residue charred so that it comes out as black ash which runs from the end of the incinerator on to the floor. The source of heat is the white-hot gases from the smelting furnace. This black ash is then shoveled over, sulphate of soda added thereto and thoroughly mixed therewith. Wood is now thrown into the smelting furnace and this black ash shoveled on top of the wood. Air from a positive blower is injected about 15-20 inches from the bottom of the furnace and the black ash burned, reducing part of the sulphate of soda to sulphide of soda according to the following equations:



Also part is reduced to carbonate of soda with small amounts of caustic soda and sulphate of soda passing through unchanged. The soda content in the black liquor is mostly reduced to carbonate of soda though part is also reduced to sulphide of soda. The molten alkali liquor runs from a spout into a dissolving tank in which is an agitator, while the hot gases pass through the incinerator charring the carbonaceous residue, making black ash in the front part of the incinerator and evaporating water in the further end of the incinerator, thence going through the disc evaporators and out of flue as above described.

This liquor in the dissolving tank is pumped to the alkali room where it is tested and the requisite amount of lime is added whereby the sodium carbonate is converted to caustic soda. This is decanted by allowing the calcium carbonate to settle and withdrawing the supernatant liquor by means of a siphon. The first two washings are added together while the weak liquor of the last washings are pumped to the dissolving tank, and this constitutes the liquor in the dissolving tank into which the molten alkali runs as above stated. The strong washings constitute the cooking liquor for the digester, though some strong black liquor may be added as a diluent.

This, in brief, is a description of the chemical end of the sulphide process.

DRAWBACKS OF PROCESS

Now let us consider what is wrong about the above process from the standpoint of a chemical engineer.

The process being a cyclic one, it obviously makes no difference at which point we start so long as we complete the cycle. Accordingly I shall start with the evaporation of the liquid.

(1) From the above it will be seen that the process described is one of direct evaporation, the only good reason for the same being the difficulty of accomplishing it by multiple-effect evaporation. It will be noticed that there is a consumption of wood in addition to the heat evolved from the solids of the liquor itself. This consumption of wood I wish to state is in order to get over *mechanical* difficulties rather than an absolute necessity. The consumption of wood is small in amount and is well paid for in the increased production and saving of labor. Even if the sources of heat for evaporation were entirely waste heat, i.e., heat which cannot be recovered and used in other parts of the mill, there is still a sound basis for putting in a multiple effect system and those who argue to the contrary have an incomplete understanding of the problem involved. Suffice to say for the present that for every pound of solid matter in this liquor there are 5000 B.T.U., which is sufficient not only to do its evaporation but furnish heat to *eliminate the wood bill* and materially reduce the amount of coal consumed in the boilers.

(2) The disc evaporators get out of order and are a constant source of expense. The liquor has a tendency to polymerize and this clogs the disc evaporators. This polymerization is due to the hot flames through which it passes, not its concentration.

(3) The variations in the original strength of the black liquor are passed right on to the incinerators which are unable to take care of these variations.

(4) The incinerators have a habit of "ringing up" in the inside, one side of the ring having molten alkali, the other side of the ring having black liquor. Now when this ring breaks, the liquor runs on top of the molten alkali and an explosion follows. If this ring is located near the end the chances are that one or more men go to the hospital for burns, and the fear of things like this happening tends to prevent the keeping of men long enough in this department for them to become expert.

(5) The unevenness of the fire in the smelting furnace can only

have one result, viz., the rapid deterioration of the furnace, not only from expansion and contraction but also from the stuffing action of the sodium sulphide sublimed with sodium carbonate followed by the oxidizing action of the air under these intermittent conditions of running.

(6) The fine particles of salt cake and alkali are carried from the furnace through the incinerator and disc evaporators and lost with the exit gases.

(7) The separation of the carbonate of lime in the causticizing room takes a very large equipment and is troublesome in the extreme if the liquor happens to contain even a small percent of iron sulphide. It usually takes six hours to settle a tank once and the heat lost is considerable of an item. The chances of losing alkali in the sludge are considerable either through accident or neglect of duty.

(8) The sludge which has a value in itself is lost and may be treated for lime if so desired.

(9) There is also the possibility of the lime getting into the pulp through careless siphoning here.

(10) The steam which is separated from the relief of the digesters being blown directly into the water which washes the pulp blows many impurities therein which gives the pulp, and consequently the paper made therefrom, an odor which prevents it being used for some purposes, for example, flour bags.

(11) This relief contains somewhat over two hundred gallons of turpentine a day which is equal in quality to the best gum turpentine. By the above method all this turpentine is lost.

(12) Now taking up the process of blowing the digester we find that a considerable amount of pulp is blown through the vomit stack and lost.

(13) Every digester blown discharges 18,000 lbs. of steam into the atmosphere, the heat of which might be advantageously recovered and used in the mill.

(14) When we come to the washing of the pulp we find the process slow and cumbersome. A process full of inherent difficulties of clogging which either means a check in production or a waste of alkali. Both of these usually occur.

(15) An appreciable amount of pulp is carried away in the digester liquor.

METHODS OF OVERCOMING DRAWBACKS

Having pointed out the objectionable features of the process as ordinarily carried out, let us consider the methods by which they were overcome and the experiments relating thereto.

EVAPORATION

As before stated, this black liquor is very cantankerous, foaming under the least provocation. Bearing this in mind we built a multiple effect evaporator specially designed to overcome this fault. At first we could not run it at anywhere near its theoretical capacity on account of the foaming propensities of the liquor. Among the experiments we tried was to run the foam and steam through a specially designed centrifugal steam separator run at a very high velocity by a direct-connected steam turbine, the object being to throw the separated liquor through periphery, letting the steam pass through the center to the next effect. This worked very well when the bubbles of foam were large, but when they were small and consequently compact and heavy there was not enough power in the turbine to carry on this increased amount of work. Neither was it advisable to make larger turbines because the power required was so great that the steam consumption would be so great that most of it would have to be wasted as only a small portion could be used in the evaporators.

We finally carried the liquor only about $1\frac{1}{2}$ to 2 inches in the tubes in the first effect, 6 inches in the second effect and increasing heights as the concentration proceeded. The principle of this objection was that foam was constituted of a globule of steam surrounded by a heavy film of liquor and that if we could produce the foam and evaporate off the water in the film to make it break we should accomplish our purpose. Now the height at which the liquor stands in the tube limits the quantity of the resulting foam, other conditions such as steam pressure density, etc., etc., being equal. Now this foam shooting up through the remainder of the hot tubes has its films transformed into steam, so that there is so much steam and so little film that they readily separate, the steam passing to the next effect and the liquor is returned to where it finds its way to the next effect. Care, however, must be taken that too much of the foam shall not be evaporated, as gumming up of the tubes results. The

levels were for a time maintained by specially designed floats and this was continued until the men got so expert that they were no longer necessary. Large separators were put between each effect to catch any occasional foam and return it to its proper effect. A solenoid was installed which could be regulated so as to return any liquor having over a predetermined strength and this could be regulated with the greatest nicety. Owing to the mercaptans given off in the liquor which have a very corrosive action we found that we had to redesign many parts of the vacuum pump and substitute rubber rings for the cast-iron piston rings. We got rid of the calcium sulphate which precipitated on tubes by surrounding the tubes with water and putting an acetylene flame down through the tubes, thereby heating the calcium sulphate and cracking it off without overheating the tubes. What with redesigning condensers and other apparatus we finally evolved an evaporator of six effects capable of evaporating considerably over 4,000,000 lbs. of liquor a day to a consistency of from 33° – 35° Bé., and we have now obtained a uniform liquor. These multiple-effect evaporators made the disc evaporators obsolete and they were scrapped and all the resulting repairs, labor and shut-downs eliminated.

ELIMINATION OF INCINERATOR AND EXPERIMENTS RELATING TO IT

Now, having obtained a uniform concentrated liquor, we are in a position to start work on the elimination of the incinerator. In order to do this several preliminary experiments became necessary which at first sight may seem to have no connection therewith. Previous experiments had shown that iron would not stand either the alkali liquor or the alkali gases under the usual conditions. Experiments were now conducted to see if it would withstand these if kept at temperatures not exceeding 400° F. The preliminary experiments seemed to show that it would, so we then obtained a steam boiler, erected it and built a smelting furnace in front of it, passing gases **under** the boiler and **through** the tubes just as if we were burning coal. Before starting we had an Inspector from the Hartford Ins. Co. go over the boiler and test it thoroughly. We then operated this boiler under 100 lbs. pressure for about a year under these conditions, and had a re-inspection by the same man and found that it had not deteriorated under these conditions any more than the corresponding deteriorations of a boiler running with the ordinary coal fire. Of course, we had trouble with saltcake subliming and

vaporizing and condensing on the boiler and fouling the tubes, but we, at this time, were not interested so much in this aspect of the case as we were in ascertaining if the boiler would stand up under these conditions.

Having satisfied ourselves absolutely that the boiler would stand up, we next tackled the problem of burning the liquor in the furnace in order to save the heat in the boiler.

Now a few words as to the nature of the residue obtained from evaporating the water from the black liquor. This is a dark-brown plastic or semisolid according to the temperature. At temperatures of steam it melts forming a sticky, gummy mass, impossible to handle in any known manner. Even in the cold it cannot be chipped, disintegrated, handled or conveyed in any known manner, and two lumps placed one on the other will nevertheless coalesce into one another. It is a most difficult substance to handle. It was thought that if this could be absorbed in sawdust, that we could evaporate the water with furnace gases. We put in a drying tower composed of shelves, plowing the sawdust alternately in and out from shelf to shelf, running the black liquor thereon and passing the flue gases over it from bottom to top. The dried, impregnated sawdust was then carried by conveyors to the furnaces. This worked as long as there was sawdust enough from the sawmill. But there was never sawdust for more than 20% capacity. We then tried hogging wood, but this got us into trouble at once and it was found that owing to the low absorptive capacity of the hogged wood, that it was impossible to build a drying tower strong enough to deal with the resultant sticky mass. We went from 6-inch I-beams to 15-inch I-beams, but found we would twist off the latter almost as rapidly as the former. We even tried using black ash as an absorbent for the black liquor. When it worked the reduction in the furnace was excellent, though it was found the resulting amount of iron in the liquor produced made the problem of settling out of the lime sludge a very difficult one. However, owing to mechanical troubles this was found, as above stated, absolutely impracticable and had to be abandoned.

We had some time previously tried to atomize this liquid into a hot flame, hoping to evaporate the water from it and have it charred by the time it landed 7 feet away, but without success, and the reason is very clear, if one considers the difficulty of getting a fine spray with this liquor.

A simple calculation will show that for the evaporation of the water alone, say nothing of charring, the diameter of these droplets could not be over .0029 inch if evaporated in gases at 2000° F. traveling a distance of 7 feet, heat abstracted from gases .005 inch thickness surrounding the droplets during the entire passage through the furnace, liquor 50% water and temperature 210°.

Now, as a matter of fact, this liquor cannot be atomized to this fineness or anywhere near it, so though we started with a good fire, we soon put it out by plastering it over with this liquor.

Now, after this drying tower proved such a failure, our minds turned back to our atomizing experiments. If we could only atomize finer and get some additional heat, we figured that it ought to be done this way. There was some chance, that by experimenting we might make an improvement in atomization and it occurred to us that the additional heat might be obtained from radiation. Stefan's law naturally occurred to our minds at this stage of the proceedings, and we at once collected all the data relating thereto to see if we could make a practicable use of the same.

This law is in brief, that the heat radiated from one black body to another varies directly as the difference of the fourth powers of the absolute temperatures. This may be expressed as follows:

$E = K(T_2^4 - T_1^4)$ where E is the total energy radiated and K a constant, T_2 and T_1 being absolute temperatures of which T_2 is the higher.

It is not our intention in this paper to drag it out to an interminable length by going into the mathematics of this law, which have been so well established that anyone interested may refer to the references given at the end of this paper.

We have, however, calculated certain results and submit these in the forms, viz., the tabulated and the graphical chart. The calculations finally reduce down to the following simple formula:

$$\text{B.T.U. per sq. ft. per min.} = 2.66 \times 10^{-11} (T_2^4 - T_1^4).$$

CALCULATIONS

ASSUMING STEFAN'S LAW FOR BLACK BODIES

ENGLISH UNITS $K = 2.66 \times 10^{11}$ B.T.U. per min. per sq. ft.

$$\text{B.T.U.} = K(T_2^4 - T_1^4)$$

Case I. $T_1 = 600^\circ \text{ F. abs.}$ T_2 varies.

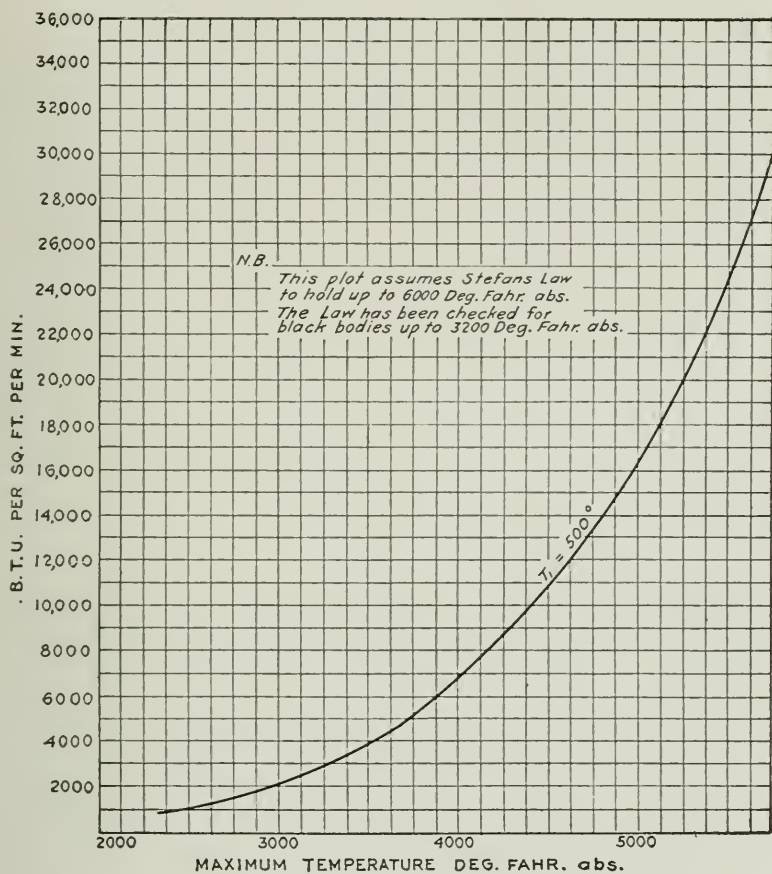
T_2	T_1	T_2^4	T_1^4	$T_2^4 - T_1^4$	B.T.U.
800°	600°	409×10^9	1295×10^8	279.5×10^9	7.43
1000		100×10^{10}		870.5×10^9	23.15
1200		2075×10^9		194.6×10^{10}	54.80
1400		384×10^{10}		371×10^{10}	98.80
1600		655×10^{10}		642×10^{10}	171.0
1800		105×10^{11}		103.7×10^{11}	276
2000		160×10^{11}		158.7×10^{11}	422.0
2500		390×10^{11}		388.7×10^{11}	1034
3000		810×10^{11}		808.7×10^{11}	2150
3500		150×10^{12}		150×10^{12}	3990
4000		256×10^{12}		256×10^{12}	6810
4500		409×10^{13}		409×10^{12}	10900
5000		625×10^{12}		625×10^{12}	16600
5500		915×10^{12}		915×10^{12}	24300
6000		130×10^{13}		130×10^{13}	34600

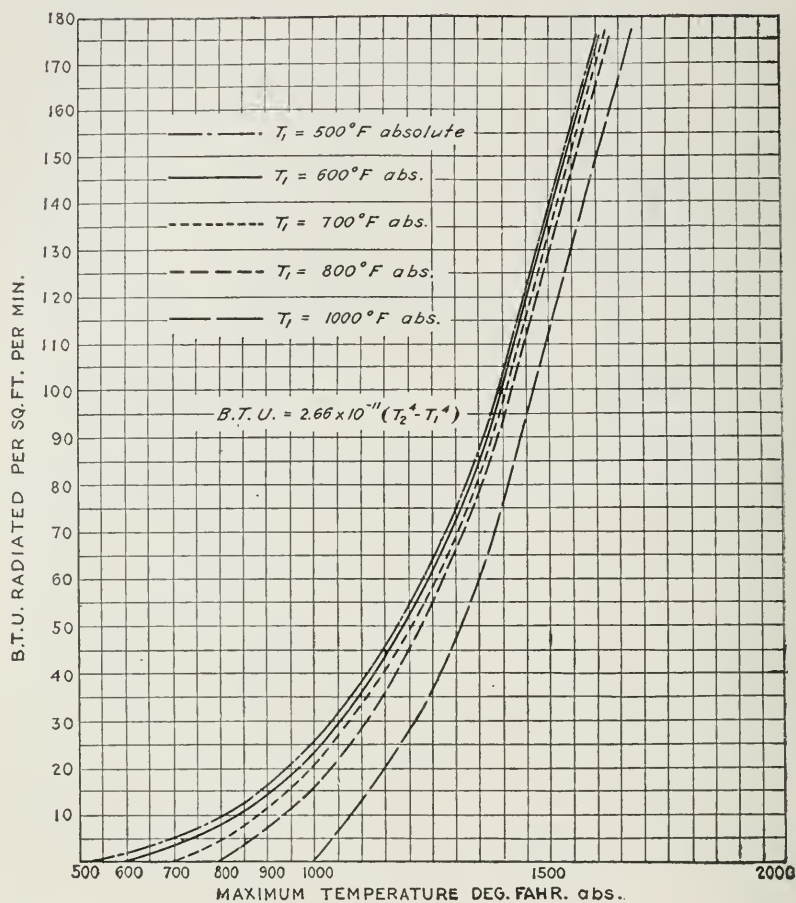
CALCULATIONS

ASSUMING DIFFERENT LOWER TEMPERATURES FOR DIFFERENT CASES

Case II, $T = 500^\circ \text{ abs.}$ Case III, $T_1 = 700^\circ \text{ abs.}$ Case IV, $T_1 = 800^\circ \text{ abs.}$ Case V, $T_1 = 1000^\circ \text{ abs.}$

CASE II.		CASE III.		CASE IV.		CASE V.	
T_2	B.T.U.	T_2	B.T.U.	T_2	B.T.U.	T_2	B.T.U.
800°	9.20	800°	4.5	800°	0	800°	.....
1000	24.90	1000	20.2	1000	15.8	1000	.....
1200	43.50	1200	48.8	1200	44.3	1200	28.6
1400	100.40	1400	95.7	1400	91.2	1400	75.5
1600	172.50	1600	167.9	1600	163.0	1600	147.5
1800	278.0	1800	273.0	1800	268.0	1800	252.5
2000	424.0	2000	419.0	2000	414.0	2000	399.0
2500	1034.0	2500	1030	2500	1027	2500	1001
3000	2150	3000	2147	3000	2143	3000	2125
3500	3990	3500	3985	3500	3980	3500	3970
4000	6810	4000	6810	4000	6810	4000	6800
4500	10900	4500	10900	4500	10900	4500	10880
5000	16600	5000	16600	5000	16600	5000	16600
5500	24300	5500	24300	5500	24300	5500	24300
6000	34600	6000	34600	6000	34600	6000	34600





In order that there may be no mistake as to what radiant heat is I will state that it is the heat which passes from a body of higher temperatures to a body of lower temperature through an intervening gas without heating that gas. Thus the heat of the sun heats the earth without heating the intervening air. The earth in turn heats the air. The so-called steam radiator heats by convection, not by radiation. It must be borne in mind that this is not a simple process of evaporation and that this is not the main object in view. The main object in view is the recovery of the alkali present in the digester liquor and that this must be a reducing process.

This liquor after the water has been evaporated analyzes 45% ash and 55% combustible, which is spoken of in the paper as lignin though it contains sugars as well as lignin, the approximate formula for which being $C_{29}H_{22}O_{11}$. This so-called lignin contains about 36.2% combined water. Analysis shows that 2 lbs. of the 50% liquor contains 1 lb. water of solution, .2 lb. of combined water and .35 lb. of carbon, .45 lb. of ash. For this amount of liquor .14 lb. of saltcake may be added.

The heat required for evaporation and combustion may be calculated to have the following distribution:

B.T.U. required to evaporate 1 lb. water at 212°	1052
B.T.U. required to raise this to 1600° F.	788
B.T.U. required to raise combined water to 1600° F.	157
B.T.U. to raise products of combustion (12% CO_2) to 1600° F.	2918
B.T.U. required to melt .45 lb. ash in liquor.	164
B.T.U. required to raise .45 lb. ash to 2000° F.	43
B.T.U. required to melt .14 lb. saltcake.	51
B.T.U. required to raise this to 2000° F.	13
B.T.U. required to reduce .59 lb. of Na_2SO_4 according to following equation:	



	5332
B.T.U. figuring loss through furnace walls 10%	533
Total heat.	5865

It will be seen from the above that the heat in the liquor, viz., 5000 B.T.U., falls considerably short of the theoretical heat needed to carry on the reaction and that it is this deficiency which must be supplied by radiant heat.

On the other hand it will be seen that a part of this heat is available for making steam if a steam boiler is placed in the pathway of the hot gases.

If we reduce the gases from 1600° to 500° we get:

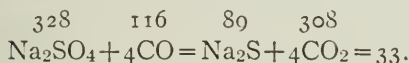
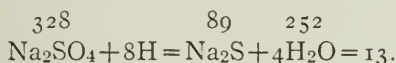
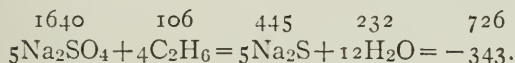
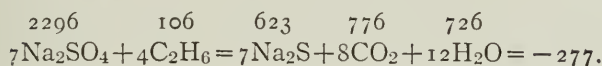
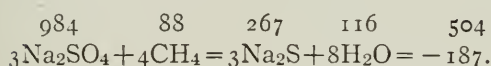
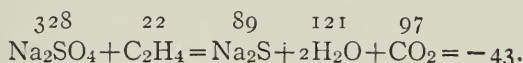
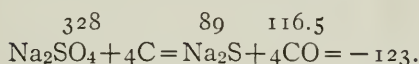
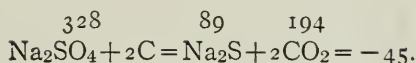
B.T.U. from superheated steam.....	610
B.T.U. from products of combustion.....	2138
Total B.T.U. available for making steam.....	2748

Now we come to the problem of making up the deficiency. There are several ways by which this might be done but only a few are practicable. If we had plenty of cord wood, we could make it up in this way and, in fact, we did at first. The results, however, were not satisfactory from the reduction side of the case. Coal can be atomized in the furnace and burned, but as all coal contains iron, it is objectionable on account of the difficulty of settling of the alkaline liquors which is occasioned by the iron. Furthermore, the coal contains ash which uses up the alkali, forming silicates and aluminates of soda, etc. It is also not satisfactory from a reduction point of view, as it requires an oxidizing flame.

Atomized crude oil was also tried, and though this gave a very hot flame furnishing the necessary amount of heat, it is not satisfactory from a reduction standpoint. Furthermore, the vaporization of the oil produces a cool zone in the place where it is necessary to have a hot zone tending to chill the smelted effluent.

Producer gas seems at present to be the most satisfactory way of supplying the extra heat needed. This enters the furnace hot and quality and quantity of the gas can be easily regulated. By constantly feeding the Producer, we get a gas containing a large quantity of illuminants which are heated to high temperatures upon combustion of the gas and radiate heat to the particles of liquor to be evaporated and these can be heated to a very high temperature by the burning of the already hot gas furnishing more illuminants.

Now if you will consider the following reactions, I think you will see the utility of this gas for reduction purposes.



The numbers given in the above equations are in large calories per gm. molecular wt. taken.

It will also be seen that in all cases except the last two the reaction is endothermic. In the last two, viz., saltcake and hydrogen, and saltcake and carbon monoxide, the reaction is exothermic. Now if we could have either pure carbon monoxide or pure hydrogen come in contact with molten saltcake, we should have a reducing action which would not chill the molten liquor so as to congeal it.

In order that there may be no misunderstandings, I want to say that the operations mentioned in regard to reduction in this paper must not be considered as taking place on pure sodium sulphate nor should the resulting product be considered as pure sodium sulphide. In every case we have a mixture of several ingredients, viz., sodium carbonate, sodium sulphate, sodium sulphide and probably a little sodium oxide. Sodium sulphide pure does not melt at 2000° C. and in order that this should run at ordinary temperatures it must be dissolved in other salts.

Now in the above figures we have figured the saltcake as if all was reduced by the carbon in the lignin liquor. We did this in order

to show the distribution of heat and the total heat consumed. As a matter of fact, however, I doubt if very much of this salt is reduced by the carbon of the lignin as the lignin is burning in an oxidizing atmosphere and any sodium sulphide reduced here from contact with the heated carbon would to a large extent be oxidized to sulphate of soda. In fact there is a considerable amount of sulphate of soda found in the smelted effluent of the furnace. The reduction caused by the lignin may be greatly increased by the producer gas. This has been shown many times by stopping temporarily the gas and the liquor and testing the effluent. The reduction of this gas was so marked that many experiments were conducted, the main object being to obtain a better mixture of this gas with the effluent. In all these experiments the reduction was markedly increased but most of them were abandoned owing to mechanical difficulties which developed.

CALCULATED AMOUNT OF COAL TO BE BURNED IN PRODUCER

The question now arises as to the amount of coal necessary to be burned in a producer to furnish the required liquor per ton of pulp produced in the mill. From data obtained we find a coal which analyses as follows:

Fixed carbon.....	53.34%
Volatile matter.....	39.25
Moisture.....	2.66
Ash.....	4.75
Total.....	100.00

and has an ultimate analysis as follows:

Carbon.....	73.11%
Hydrogen.....	5.88
Nitrogen.....	2.10
Oxygen.....	9.24
Moisture.....	2.66
Ash.....	4.28
Sulphur..	1.73

This will give a producer gas which analyses as follows:

	By Vol.	By Weight.
Carbon dioxide.....	3.9	7.32
Ethylene.....	3.2	3.75
Oxygen.....	0.1	0.13
Carbon monoxide.....	24.6	28.86
Methane.....	3.8	2.62
Hydrogen.....	17.7	1.51
Nitrogen.....	46.7	55.81
	100	100

If we assume the gas comes from the producer at 1200° F. and that we burn it with the theoretical amount of air we find the following amounts and distribution of heat for 100 lbs. of gas:

Heat of combustion of 3.75 lbs. ethylene.....	77,560	
Heat of combustion of 28.86 lbs. carbon monoxide.....	126,200	
Heat of combustion of 2.62 lbs. methane.....	56,190	
Heat of combustion of 1.51 lbs. hydrogen.....	79,230	
Total.....	339,180	
Sensible heat 7.32 lbs. carbon dioxide.....	2,228	
Sensible heat 3.75 lbs. ethylene.....	1,820	
Sensible heat 0.13 oxygen.....	34	
Sensible heat 28.86 carbon monoxide.....	8,533	
Sensible heat 2.62 methane.....	1,869	
Sensible heat 1.51 hydrogen.....	6,494	
Sensible heat 55.81 nitrogen.....	16,500	37,478
Total.....		376,658

Now the simplest method of getting the heat radiated is to find the heat leaving in the products of combustion and subtract this from the total heat.

In doing this the following formulas are used:

$$(2405 + 0000119t)t = \text{B.T.U. for 1 lb. N.}$$

$$(.19 + .00006t)t = \text{B.T.U. for CO}_2.$$

$$(.2104 + 0000187t)t = \text{B.T.U. for 1 lb. O.}$$

$$(.2405 + 0000119t)t = \text{B.T.U. for 1 lb. CO.}$$

$$(.42 + .000103t)t = \text{B.T.U. for 1 lb. steam.}$$

Now if we assume that owing to radiation and convection the gases are reduced to 1600° F. going over the bridge wall we have a basis for getting the heat in the products of combustion. A simple calculation shows that for every 100 lbs. of gas entering the furnace we have a total of 327 lbs. going over bridge wall distributed as follows:

174.48 lbs. of nitrogen from air
 55.81 lbs. of nitrogen from producer

230.29 total nitrogen

11.79 lbs. CO_2 from ethylene
 45.97 lbs. CO_2 from carbon monoxide
 7.20 lbs. CO_2 from methane
 7.32 lbs. CO_2 from producer

72.28 lbs. total CO_2 .

Total of 327 lbs. of gases going over bridge wall for 100 lbs. of producer gas.

4.93 lbs. steam from ethylene
 5.89 lbs. steam from methane
 13.59 lbs. steam from hydrogen

24.42 total lbs. steam.

Now if we calculate the heat in these given amounts of products of combustion we find we have:

	B.T.U.
Sensible heat of above steam at 1600° F.	19,260
Heat in 230.29 lbs. nitrogen at 1600° F.	95,610
Heat in 72.28 lbs. carbon dioxide at 1600° F.	23,080

Total heat in products of combustion of 100
 lbs. of gas at 1600° F. going over bridge
 wall. 137,950

The excess of B.T.U. in the gases generated over those contained in the products of combustion at 1600° F. is found by subtracting 137,950 from 376,658 which gives us 238,708 B.T.U. for 100 lbs. of producer gas available as radiant heat to heat the particles of liquor.

Calculation from the ultimate analysis of the coal and the analysis of the gas show 1 lb. of carbon produces 3,729 lbs. of gas, or that for every pound of coal burned in producer 14,050 B.T.U. are liberated. Of course all this heat does not come from the coal, but part comes from the steam blown into the producer. Assuming a loss here also of 10% through furnace walls, we have a loss of 1405 B.T.U. to take from the heat of radiation, neglecting heat losses from furnace. We find that we get 2387 B.T.U. per pound of gas to be supplied by radiation and convection to liquor and from this we get B.T.U. per pound of coal, 8851. Subtracting from the latter the 10% heat losses for furnace, 1405, we get 7446 B.T.U. to be applied to making up the 865 B.T.U. deficiency not supplied by the heat in the lignin.

Now let us take as a unit a mill producing 100 tons a day of Kraft pulp.

Wood for making such pulp varies all the way from 45 to 52% cellulose according to kind used and location grown. Let us assume a pulp containing 48% cellulose and 52% lignin. Then a unit of 100 tons pulp would have a content of 108 tons of lignin in the black liquor.

As the dried liquor is 45% ash we find that our 100 tons of lignin makes 197 tons of dried black liquor. Then we have 394,000 of solid matter or 788,000 lbs. of 50% liquor.

Multiplying 394,000 by 865 and dividing by 7446 we find that we must have at least a producer capacity of 45,760 lbs. per day per 100 tons of pulp. Of course there should be some leeway for poor coal variations in strength of liquor.

As a matter of fact we have found a 20% margin above this not excessive when we consider the troubles eliminated by not running close to the theoretical point where any of the many variables tend to upset the operation even to the extent of clogging the furnace.

TANGIBLE RESULTS FROM ELIMINATION OF INCINERATOR

As a result, however, of the above process we have been enabled to produce over 1600 horse-power from our liquor in addition to recovering the heat generated in the gas producer. We saved all our hospital bills and damages arising from explosions, we reduced the repair bills in the furnaces enormously, we saved all the repairs on incinerator and disk evaporators and the power required to run

same, we saved about 60 men's labor in various departments and, above all, got an even, uniform production of quality never obtained before. In addition to the above it alone was the means of increasing the production many times.

KEEPING BOILER TUBES CLEAN

We have already mentioned that the boiler tubes in the preliminary experiments got dirty from sublimed saltcake and carbonate of soda. The keeping of the tubes clean proved to be a much more difficult problem than we first thought. The sublimed saltcake first deposits on the tube as a powder, but if not removed the additional saltcake soon smelts the whole to a continuous lump almost impossible to remove. The obvious remedy was to blow the tubes often enough to keep this powder from accumulating on the tubes, but how to do this without affecting the operation of the furnaces was a problem. I might also add it is still a problem, for though we have a workable proposition I think there is still a large chance for improvement. If we opened the clean-out doors we spoiled our draft and consequently had to shut the furnace down. We tried automatic blowing, but these blowers would burn off in the vaporized alkali or plug up so we could do nothing. We even had doors made with a hole covered by a small door opposite each tube, but these were unsatisfactory in that we were blowing from the wrong end and the air or steam did not have force enough by the time it got to the fire end of the tube to remove the accumulation of salt and alkali. We finally evolved a scheme by rebuilding the back of the furnaces where we could have a slot on top covered by covers and a rake attachment locating the tubes horizontally. The tube blower was also graduated by a ratchet attachment to locate the tubes vertically. By this means the tube of each boiler is blown twice a shift. Each blowing takes twenty minutes and we run three shifts; it will be seen that two hours are required for each furnace for every twenty-four hours of operation.

ADDITION OF SALTCAKE

The next problem was the constant addition of saltcake in the required quantities to the liquor. We first tried putting the saltcake in the back of the furnace through a tube supplied with saltcake by means of a conveyor. This did not give us the results desired.

inasmuch as this was not properly mixed with the liquor, and consequently a great deal passed through the furnace unchanged. In other words, our reduction to Na_2S was small and the desired liquor was not obtained. The next step was to put a horizontal agitating tank over each furnace and mixing the liquor and saltcake therein and supplying each furnace separately according to its consumption. This worked fairly well. The main objections to this was the increase in the amount of labor required and the clogging of the pipes with saltcake when it was necessary to close a valve. We were quite successful in the scheme described in U. S. Patent 1,130,317, Mar. 2, 1915, not described here on account of taking up too much space.

We finally evolved a scheme by which we put saltcake in a hopper from which it was carried to a grinder, elevated to a rotary screen and sifted, the fine particles going to a mixing tank and the coarse particles being returned to the grinder to be reground. The mixer tank was supplied with liquor from the storage tank installed to hold the evaporated liquor, and powdered saltcake added by calibrated diaphragms so that a given amount of saltcake was added for a given amount of liquor. The mixture was pumped to the furnaces through a pipe in which a very high velocity was maintained and the liquor not used in the furnaces was returned to the mixing tank also at a high velocity. The object of having a high velocity in the pipes is to prevent the saltcake, which is only slightly soluble in liquor of this concentration, from settling out. Special valves were designed on the outlets of this pipe so that they could be cleaned without stopping the operation and they were so set into the line as to prevent forming a pocket on the take-off. In addition to the above, many contrivances were adopted for handling this liquor, but as to describe them would stretch this paper to undue length I must omit them.

SETTING AND RESETTNG BOILERS

Now, having described the amount of heat coming from the flue gases of the furnaces, it might be well to state the method of recovering the heat contained therein. Experiment had convinced us that the horizontal return tubular boiler was best adapted to our needs on account of the comparative ease, as compared with other types of boilers, by which the saltcake and soda could be removed from the tubes. This we set up following the standard accepted boiler setting. This was found to be a great mistake and the settings

had to be entirely changed to meet the new conditions imposed on them. In explanation I wish to say that though saltcake, soda and sulphide of soda vaporize at high temperatures they may be sublimed at 1200° F. in a current of furnace gases. Now the shell of the boiler acts as a condenser and the hot molten alkali condensed forward of the peak in the boiler setting flowed forward into the furnace. But unfortunately all the vaporized alkali was not removed here, but a considerable amount was condensed on the boiler back of the peak and this either accumulated as a lake of molten alkali or gradually solidified or ran out of the clean-out door onto the blow-off pipes or the cement floor. I have at times seen streams of molten alkali as large as my arm so run out of these clean-out doors.

These furnaces had all to be rebuilt with a continuous slope from the clean-out doors to the furnace. Even the whole length of the shell of the boiler was insufficient to condense all the sublimed alkali and this would accumulate in the tubes at first as a powder, but if the tubes were allowed to get too dirty, the powder, being a nonconductor of heat, insulated the boiler tubes and the next accumulation of sublimed soda landed in the tubes in a melted condition, cementing this powder to a hard mass. Many and various were the schemes tried to get over this trouble, and we are still experimenting.

DISSOLVING TANK LIQUOR

As previously stated, the smelt runs into the dissolving tank where it is dissolved in the weak alkali coming from the alkali room. Owing to the greater efficiency of reduction we obtained a dissolving tank liquor much stronger in sulphide content than ever obtained before. Owing to the elimination of the incinerator and the intermediate black ash process the sludge in the dissolving tanks is very much reduced and the pieces of half brick, stones, etc., are reduced to a minimum; thus the constant repairs of agitator arms, etc., were eliminated.

FLUE GASES

The gases from the smelting furnaces contain considerable quantities of alkali irrespective of whether the old or the new process just described is used. This alkali is in such a fine state of subdivision that it is practically impossible to remove it by any of the ordinary means. These gases were run through a tower filled with atomizers, filling the tower with a dense fog and yet the particles were so fine

that they would not be precipitated. We finally decided to experiment with the Cottrell Process and made arrangements for the same with the Western Precipitator Co. Owing to the great quantities of moisture in our flue gases we were not very successful at first, inasmuch as the moist precipitate would short-circuit the apparatus. But after making many changes we finally evolved a modification of this process which works finely. This not only prevents a public nuisance but it yields large dividends from the saving of this precipitate.

FILTRATION OF DISSOLVING TANK LIQUOR

As stated before, the dissolving tank contains many impurities among which are carbon, furnace linings, iron sulphide, etc., etc. Now the treatment of this liquor depends on the question of whether or not you intend to recover your lime. If the lime is not to be recovered this liquor can be pumped directly to the causticizing tanks. If, however, it is the intention to recover the lime it is necessary to filter this liquor from all the suspended matter, otherwise every time the lime was recovered there would be an addition of these impurities which would make the recovery impracticable. We have found that the best way to handle this is through a filter press. Here, however, we run up against a great difficulty, though this first made itself apparent in the causticizing operation to be described later on. The canvas used in the filter press does not stand alkali and required renewal so often that it was a source of considerable expense. This difficulty was partially overcome by treating it with a special rubber solution, depositing the rubber on the canvas threads and yet leaving the cloth porous. There is still chance for improvement here. The liquor after being filtered is sent to the alkali room.

ALKALI ROOM

In this room the liquor from the dissolving tank is causticized. This room consists of a large number of settling tanks fitted with siphons, lime, baskets, agitators and steam pipes for blowing in live steam. Here the liquor is tested and the calculated amount of lime added to the slacking baskets, steam blown in and the tank agitated, after which the precipitated carbonate of lime is allowed to settle. The supernatant liquor is siphoned off and weak liquor added from a previous washing and the operation repeated. Finally, the fourth

washing is done with water after which the sludge is sluiced. As will be seen this process involves a large installation and requires a considerable amount of steam as well as considerable amount of time. Now the time factor is important inasmuch as if anything happens so that you become short of cooking liquor the digester plant has to shut down more or less waiting for these tanks to settle. Furthermore, the very nature of the process is such that it invites waste by either not washing properly due to neglecting one washing or due to incomplete settling on account of trying to catch up with the digesters, or losses may occur easily by intentional or unintentional manipulation of the labor employed.

In order to eliminate these wastes a filter press was installed which enables us to dispense with the settling and leaves many of these tanks available for storage of liquor. The lime sludge can be washed in the filter press with much less water than is used in the decanting or settling process and may be washed much freer from alkali. Furthermore, if the dissolving tank liquor has been filtered the lime sludge is in a condition for recovery of the lime. This operation allows us to make a stronger alkali solution than we otherwise could, and consequently we can use more black liquor as a filter in our digesters later on. This also means less evaporation later on.

RECOVERY OF LIME SLUDGE

We have experimented quite successfully on the recovery of the lime sludge, but up to the present have not put in an industrial plant. As this is not operating on a large scale I will not go into this here, but may in a future paper show how this is done. The method which gives the greatest promise is the Electric Furnace method, whereby we get pure CO_2 and recover our lime. We have installed a large experimental electric furnace with this end in view and expect to work it when our water-power development is completed.

DIGESTER HOUSE

The alkali from the filter press goes to storage tanks and thence to the digesters already filled with chips, where it is mixed with a certain amount of black liquor (used as a filler). The digester is steamed and cooked in the usual way. We, however, made one very important change here. Instead of blowing relief into water

to heat it we constructed a condenser and condensed the relief after first having separated it from the liquor which is contained.

There were three objects in view here. First, there was a limitation placed on the use of our pulp for many purposes, owing to the odor in bags used for holding flour, etc. My experiments had convinced me that a lot of this odor came from the use of this wash water. To get rid of this odor was the primary object but of course we wanted to save the heat.

Turpentine Recovery.—Our experiments had also shown that this relief contained large quantities of turpentine which, with the exception of the odor, tested equal to the best gum turpentine obtainable and far superior to wood turpentine. We consequently constructed, in addition to the condenser and separator plant previously mentioned, a turpentine plant in which we separated the crude turpentine, made refined turpentine and finally a plant for deodorizing it from the mercaptan smells which accompany it. We have not been able to completely remove the odor, but have so far succeeded that we are enabled to sell our whole production at good prices.

VOMIT STACK GASES.

After a digester is cooked the charge is blown into tanks to receive the pulp and liquor and the liberated steam is allowed to escape through a vomit stack. A calculation showed that there might at times be as much as 18,000 lbs. of steam liberated in the course of a five-minute blow. Now here is over 20,000,000 B.T.U. per blow going to waste.

To save this we designed special condensers to condense this steam and heat the condensing water so that it could be used for washing the pulp.

VOMIT STACK PULP

Experiments had also shown that this vast amount of steam carried along with it a certain amount of pulp which except for these experiments would have entirely escaped our notice. This pulp, however, which is of the finest quality and should be saved for its own value, must be removed from the vomit stack steam before it enters the condenser, otherwise the plugging of the condenser is liable to follow. To do this we designed a special separating device somewhat on the principle of the cyclone so com-

monly used in separating shavings from air. This, however, was made with a pipe in the center which was closed at the bottom and had holes in it near the top for the outlet of the escaping steam. The steam was blown in at a tangent to the separator and circulated spirally up the separator, plastering the pulp over the side by its centrifugal force while the steam, now freed from pulp, passed to the condenser. Devices were also arranged for washing this plastered pulp from the sides as soon as the blow was completed.

The above not only enabled us to save an appreciable quantity of pulp but furnished us with immense amounts of hot water practically free of cost, enabling us to make a better and cleaner pulp.

WASH ROOM

The pulp from the digester is washed in the usual manner, though even here we have devised a machine on the counter-current principles of washing which looks as if it would revolutionize the whole washing end of the business. At present it is too soon to say much about this.

LIQUOR FROM WASH ROOM

This liquor instead of going direct to the evaporators goes to a filter press, and it is found that we obtain a considerable saving in pulp. Not only this, but the removal of this pulp from the liquor makes a direct saving, not due to the pulp, but an indirect saving which is even of far greater importance. I refer to the trouble eliminated in the evaporator room by being freed from the accumulation of pulp in the last effect which seriously interferes with evaporation.

We have now completed our cycle, being back where we started. In the foregoing we have not taken into consideration all the departments of the mill. Many of these are undergoing changes, but enough has been said to show that the chemical engineer can play a most important part in the renovation of this kind of mill at least. My own personal opinion is that the chemical engineer has a great opportunity in any mill involving a chemical process. In closing I may say that the average manufacturer considers the chemist and the chemical engineer as non-productive labor and classes them with the office help. As a matter of fact, the chemical engineer can probably not only save him more money than any other department of his mill but also produce him more money.

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DISCUSSION

Dr. CHARLES S. PALMER: I think this is one of the most monumental papers in showing what a high-grade chemical engineer can do with hard problems that I have ever seen or heard of and there is an enormous amount of material we should take up. I have only one or two very superficial questions I would like to ask right now. What was the price of coal up there, roughly?

Mr. HUGH K. MOORE: About \$5 a ton; not quite \$5 a ton; I forget the exact figures.

Dr. CHARLES S. PALMER: I would also like to ask, on page 183, speaking of the effect of the multiple evaporator you mention here: "We got rid of the calcium sulphate which precipitated on tubes by surrounding the tubes with water and putting an acetylene flame down through the tubes, thereby heating the calcium sulphate and cracking it off without overheating the tubes." There was no other accumulation in the tubes excepting that calcium sulphate to bother you? The foaming did not produce any sticky material to bother you?

Mr. HUGH K. MOORE: No. We had a foam which is largely phytosterol which gives all kinds of trouble, but that did not give us the trouble there.

Dr. CHARLES S. PALMER: You could keep the tubes of the multiple effect clean, and in every case you used an ordinary type, I understand?

Mr. HUGH K. MOORE: Yes. There was some scale (indicating bottles of scale). That, however, did not come from the inside of the tubes; that came from the outside of the evaporator. The inside of the tube, however, is of the same nature, only it is a little whiter.

Dr. CHARLES S. PALMER: And that is what you removed by the acetylene flame?

Mr. HUGH K. MOORE: Yes, that is what we removed by the acetylene flame; broken up, of course, to get into the bottle.

Dr. CHARLES S. PALMER: In how large pieces would it come off?

Mr. HUGH K. MOORE: Oh, I could not say. Maybe it would come off in pieces from the size of a pinhead to cylinders, almost.

Dr. CHARLES S. PALMER: Six or eight inches long?

Mr. HUGH K. MOORE: Well, they would not be cylinders 6 or 8 inches long; but they would be slabs or arcs though hardly 6 or 8

inches long—not quite as long as that, I should say on the average. Of course, sometimes you get a big slice, but anywhere from a small piece up to 3 inches.

Mr. HARRY O. CHUTE: This description of the multiple effect work is extremely interesting to those who have been through some of the same troubles and have not solved them perhaps as well as the author of the paper to-night has.

Do I understand that the multiple effect was of the ordinary tube type with the tube say from 2 to 4 inches in diameter and 2 to 6 feet long, within those limits, and that you could put an acetylene torch down through the small tubes of that size?

Mr. HUGH K. MOORE: I designed those evaporators myself; I can tell you exactly what they were. The tubes of those evaporators are 2 inches, that is an outside diameter of an evaporator tube, and 7 feet long.

Mr. HARRY O. CHUTE: In about 1896 I became familiar with the reduction or concentration of soda pulp liquor, which was then almost exclusively done in Yarrien multiple effects. The Yarrien, as perhaps some of the older members know, has largely disappeared in this market. It was a horizontal tube machine in which a spray of liquid passed through a number of tubes giving this film effect that the author speaks of, and that seemed to be a successful type for soda pulp liquor. The removal of scale has caused all of us perhaps more or less trouble and it certainly is a very valuable suggestion. At the risk, perhaps, of telling some stories out of school, I am going to say that I had occasion to examine a multiple effect a little while ago that was used in evaporating brines from bitterns, and it was supposed that magnesium sulphate had crystallized on tubes and formed a scale, and it had compelled the removal of the boiling chamber and the substitution of a new one. It is evident that this might have been removed by this acetylene process, saving the price of a new boiling chamber, and this hint as to the method of removing scale is extremely valuable, I think, to a number of us.

I did not quite understand the subsequently treatment of the liquor, although in evaporating in a multiple effect of late years, even with the Roberts vertical type, which usually has 2- to 4-inch tubes about 3 or 4 feet in length, it is customary to run now with a very shallow liquor level; that is, we have only say 6 to 8 inches of liquor level and let the liquor flow up through the tubes as a film or spray. That is used in many industries, including the sugar

industries of late, and the film evaporation is being used even with the older type of evaporators and many new types of evaporators use that film evaporation.

I would like to inquire whether this furnace which was substituted for the rotary furnace was a flat type of furnace and was it a cupola furnace or a smelting furnace operated and if it was operated what became of the fumes from the smelting furnace? I did not quite get the process after it had been reduced with the new multiple effect.

Mr. HUGH K. MOORE: Well, now, if I understand you right, do you want me to trace out the course of the liquor as to what becomes of it after it comes out of the multiple effect?

Mr. HARRY O. CHUTE: Yes.

Mr. HUGH K. MOORE: This liquor from the multiple effect goes to a storage tank; then it is fed into a mixing tank and at a certain given rate salt cake is added——

Mr. HARRY O. CHUTE: Salt cake is added before it goes into any furnace at all?

Mr. HUGH K. MOORE: Before it goes into any furnace at all, through a calibrated diaphragm, so that according as the liquor is flowing, according to your consumption of liquor, you add a calibrated amount of sulphate ground and dried so that it runs through this diaphragm. Then it is atomized into the furnace.

Mr. HARRY O. CHUTE: That is, the mixed liquor is atomized into the furnace?

Mr. HUGH K. MOORE: The mixed liquor is atomized into the furnace.

Mr. HARRY O. CHUTE: This is a stationary furnace, a flat type furnace?

Mr. HUGH K. MOORE: A flat type furnace. No, it is not exactly; it has a sloping bottom about like that (indicating) so that the whole liquor runs out as a molten alkali.

Mr. HARRY O. CHUTE: It runs down an inclined plane?

Mr. HUGH K. MOORE: It runs down an inclined plane as a molten alkali. That liquor is atomized and is going a distance of 8 feet at a rate of about 1.400 feet in a second, and yet that liquor lands dry on the other side, burned down, owing to the radiant heat which I speak of in the paper.

Mr. HARRY O. CHUTE: This furnace combines then the rotary furnace and smelting furnace, does it?

Mr. HUGH K. MOORE: Why, yes, if you want to put it that way. You atomize it in there and then it smelts it out. This flow of gases condenses under the boiler and you condense great quantities of liquid similarly on the bottom of the boiler.

Mr. HARRY O. CHUTE: The air comes with the spray; the air could not go against the spray?

Mr. HUGH K. MOORE: No, the air makes the spray. We compress that air to 100 pounds pressure and drive this liquor through a slot .006 of an inch in diameter. That slot is liable to wear and if it gets to be ten-thousandths of an inch in diameter you cannot do the trick; then the gases pass under the boiler and through the furnace up the flue and is precipitated by the Corona discharge.

Mr. HARRY O. CHUTE: You use no wood for smelting?

Mr. HUGH K. MOORE: No wood at all, except once in a while when the foreman is not watching they are liable to throw in some.

Mr. HARRY O. CHUTE: The producer gas goes in parallel with the spray?

Mr. HUGH K. MOORE: No; the producer gas enters at the bottom of the furnace and impinges on this molten alkali and CO and the hydrogen tends to reduce the sulphate of soda to sulphide of soda.

WASTE HEAT UTILIZATION

By H. D. BAYLOR

Read at the Buffalo Meeting, June 20-22, 1917

In the burning of Portland cement in a modern rotary kiln only about 35 to 40 per cent of the heat received by the kiln is used in decomposing the carbonates and forming clinker, the remainder being lost through radiation and conduction or carried away by the stack gases and discharged clinker.

A great many schemes have been proposed to recover these different losses, but since the waste stack gases perhaps afford the easiest plan of attack, this particular phase of heat recovery is receiving more attention than any of the other losses. In this direction various devices have been tried out with more or less success, such as the use of waste heat in drying the raw materials preparatory to grinding, the heating of feed water for steam purposes and the direct generation of steam by means of boilers of various types. The last mentioned appears to give more promise than any of the other ideas thus far advanced. Perhaps the first installation of a boiler for waste heat recovery in connection with a rotary kiln was the one erected at the plant of the Cayuga Lake Cement Co. Since that time two or three other plants have erected boilers along somewhat similar lines such as those erected by the Kosmos Portland Cement Co., Kosmosdale, Ky., the Sandusky Portland Cement Co., Dixon, Ill., and the Burt Portland Cement Co., Bellevue, Mich. But the boiler with which the writer is most familiar and on which the following data were obtained is the one recently installed at the plant of the Louisville Cement Co., Speeds, Ind. This installation consists of a B. & W. waste heat boiler of modern design, with a rated horse power of 1500, having 15,300 sq. ft. of heating surface and originally 1382 sq. ft. of superheating surface, but due to the close spacing of the tubes in the superheater as first

installed, trouble was caused by dust caking between the tubes, thus cutting the draft. This difficulty has been overcome by eliminating one-half of the tubes, thereby cutting the superheating surface to 691 sq. ft. The boiler is equipped with a turbine-driven fan capable of handling the gases from two 10 by 150 ft. kilns, when operated at full capacity and to also furnish sufficient suction to overcome the friction through the boiler and gas conduit. As can be seen from a study of the table of draft readings, the draft loss through the boiler is quite high, but the fan running well below its maximum capacity handles the gas in a satisfactory manner. The turbine driving the fan is rated at 280 H. P., but under general working conditions consumes approximately 135 H. P., the drive being accomplished by means of a Falk reduction gear. The general arrangement of the kilns, gas conduit and boiler is shown in the accompanying drawings, Fig. 1.

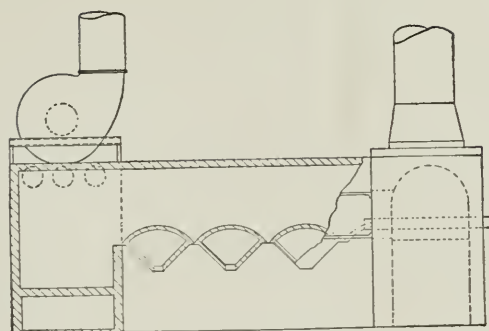
Prior to the installation of the boiler the draft on these kilns was obtained by means of stacks, each kiln having a stack 60 feet high and 11 feet in diameter, the maximum output under these conditions being approximately 900 barrels per day for each kiln, but since the erection of the boiler, with the fan equipment we have been able to so increase the draft on the kilns that the capacity will now approximate 1250 barrels per day, and this without any increase in coal consumption per barrel.

The dust accumulation on the tubes is blown off with superheated steam once every twenty-four hours. There is quite a marked saving in the amount of raw material that is recovered, due to the settling of the dust in the long gas conduit, and under the boiler, the internal arrangement of this conduit being such as to give a baffling effect. This dust is drawn from the hoppers of the conduit once every twenty-four hours; and at intervals of thirty days it is necessary to clean the dust accumulation from under the boiler. In the erection of the second boiler of this type a large settling chamber has been provided for, directly under the boiler.

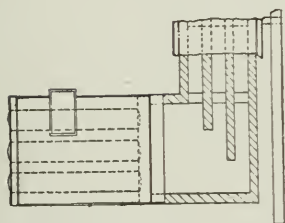
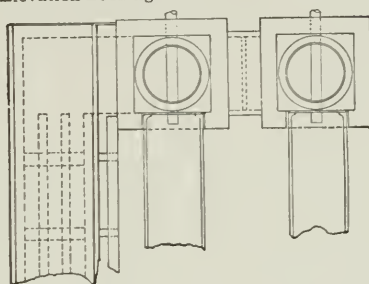
The air used for combustion of the coal is drawn over the discharged clinker and by so doing fully 75 per cent of the air entering the kilns for combustion will approximate 350° F.

The fuel used in the kilns is an Eastern Kentucky coal having a heating value of 13,300 B. T. U.

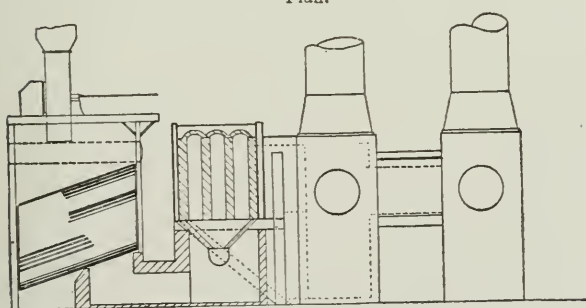
The proximate and ultimate analyses show:



Elevation Looking North.



Plan.



Elevation Looking East.

FIG. 1.—Waste Heat Boiler, Cement Kilns and Connecting Kilns.
Louisville Cement Co., Speed, Ind.

PROXIMATE

Vol. comb.....	34.22
Moisture.....	1.65
Ash.....	8.65
Fixed carbon.....	54.13
Sulphur.....	1.35

ULTIMATE

Carbon.....	74.50
Hydrogen.....	4.90
Oxygen.....	7.45
Nitrogen.....	1.50
Sulphur.....	1.35
Moisture.....	1.65
Ash.....	8.65

This coal is ground so that 96 per cent will pass the standard No. 100 mesh sieve and 80 per cent will pass the standard No. 200 mesh sieve.

To burn 1 pound of the above fuel would theoretically require 10 pounds of air.

To give some idea of the general working conditions of the kilns and boiler the following data (obtained under actual test) may be taken as representative. All temperature readings are in degrees F., draft readings being in inches of water.

Temperature of atmosphere	60
Temperature of raw mix fed to kilns	190
Temperature of pulverized coal as fired to kilns	160
Temperature surrounding kilns	80
Preheated air entering kilns for combustion ...	350
Temperature of discharged clinker	1800
Waste gases at back of kilns	1350
Waste gases entering under boiler	1275
Temperature of gases at top of first pass.....	875
Temperature of gases at top of second pass ...	720
Temperature of gases at bottom of second pass	600
Temperature of escaping gases.....	426
Temperature of steam.....	510
Temperature of feed water.....	95

Analysis of flue gas entering under boiler:

Carbon dioxide.....	16.8
Oxygen.....	8.6
Carbon monoxide.....	0.0
Nitrogen.....	74.6

The carbon dioxide content given above includes both the CO₂ of combustion and CO₂ driven off the limestone, hence our true flue gas analysis due to combustion of the coal would show

As Anal.		Due to comb.
CO ₂.....16.8	$\left\{ \begin{array}{l} \text{CO}_2 \text{ due to stone} = 5.7 \\ \text{CO}_2 \text{ due to comb.} = 11.1 \end{array} \right\}$	11.8
O ₂ 8.6	8.6	9.1
CO..... 0.0	0.0	0.0
N ₂.....74.6	74.6	79.1

Considering the above gas analysis and the analysis of the coal, we find the air actually supplied per pound of fuel = 15.3 pounds.

Draft at boiler stack breeching.....	6.80
Draft at rear pass top.....	6.20
Draft at second pass bottom.....	5.30
Draft at second pass top.....	3.95
Draft at first pass top.....	3.55
Draft at first pass bottom.....	1.37
Draft kilns entering flue.....	0.45
Steam pressure, pounds.....	154
Boiler H. P. developed.....	1160
Coal consumed per barrel clinker burned.....	94.7
Pounds raw material required per barrel clinker	605
Standard barrel cement, pounds.....	380
Pounds carbon dioxide driven off mix per barrel clinker.....	200
Specific heat of air.....	0.2375
Specific heat of coal.....	0.26
Specific heat of mix.....	0.20
Specific heat of stack gases under 450° F....	0.234
Specific heat of waste gases at 1400° F.....	0.255
Heat liberated by chemical reactions per pound of clinker formed, B. T. U.....	360*

* The above figure was taken from data obtained by Prof. W. S. Landis.

In working out the heat balance it might be well to show the source of the heat supplied to the kiln, the figures all being computed to a one-hour basis.

(1) Heat received by kiln per hour,

(a) Sensible heat received from raw mix,

$$\frac{2500}{24} \times 605 \times 0.2(190 - 60) = 1,638,520 \text{ B.T.U.}$$

(b) Sensible heat received from coal,

$$\frac{2500}{24} \times 94.7 \times 0.26(160 - 60) = 256,460 \text{ B.T.U.}$$

(c) Heat received from air for combustion,

(c-1) Pounds of air supplied per hour for combustion,

$$\frac{2500}{24} \times 94.7 \times 15.3 = 150,920 \text{ lbs.}$$

(c-2) B.T.U. in air supplied from clinker pit,

$$150,920 \times 0.75 \times .2375(350 - 60) = 7,800,000 \text{ B.T.U.}$$

(c-3) B.T.U. in air draw from kiln room,

$$150,920 \times 0.25 \times .2375(80 - 60) = 179,470 \text{ B.T.U.}$$

(d) Heat liberated by chemical reactions,

$$\frac{2500}{24} \times 380 \times 360 = 14,254,560 \text{ B.T.U.}$$

(e) Heat supplied per hour by fuel as fired,

$$\frac{2500}{24} \times 94.7 \times 13,300 = 13,900,000 \text{ B.T.U.}$$

(f) Total heat received by kilns per hour = 155,059,000
B.T.U.,

this heat in the burning process being distributed somewhat as follows:

- | | |
|--|------|
| (a) Heat required to decompose carbonates and form clinker | 37.6 |
| (b) Heat carried out in hot clinker | 10.6 |
| (c) Heat carried out in stack gases | 35.5 |
| (d) Heat lost by radiation and conduction | 16.3 |

From the above distribution of heat we have 35.5 per cent available for use under the waste heat boiler, this heat being obtained from the gases of combustion and the carbon dioxide driven off the limestone.

(1) Heat carried away by stack gases available for steam generation,

(a) Pounds of waste gas per pound of fuel,

$$\frac{(11 \times \text{CO}_2) + (8 \times \text{O}_2) + 7(\text{CO} + \text{N}_2)}{3(\text{CC}_2 + \text{CO})} \times \text{C}$$

where CO_2 , O, CO, and N are the per cent by volume from flue gas analysis, C being per cent carbon in fuel from ultimate analysis, then, by substituting, we have

$$\frac{(11 \times 11.8)(8 \times 9.1)7(079.1)}{3(11.80)} 74.5 = 15.9 \text{ lbs.}$$

(b) Total pounds of gas per hour due to combustion,

$$\frac{2500}{24} \times 94.7 \times 15.9 = 156,850.$$

(c) Pounds CO_2 given off from limestone,

$$\frac{2500}{24} \times 200 = 20,850.$$

(d) Total pounds waste gases = 177,700.

(e) Total heat actually supplied to boiler,

$$177,700 \times 0.255(1275 - 60) = 55,051,400 \text{ B.T.U.}$$

(2) Heat absorption by the boiler,

(a) H. P. developed under test = 1160,

(b) B.T.U. required to theoretically produce

$$1160 \text{ H.P.} = 970.4 \times 34.5 \times 1160 = 38,824,480 \text{ B.T.U.}$$

(3) Heat carried away by stack gases,

$$(a) 177,700 \times 0.234(426 - 60) = 1,520,000.$$

(4) General distribution of heat in waste heat boiler,

(a) Absorbed by boiler, 70.5 per cent,

(b) Carried out by stack gases, 27.6 per cent,

(c) Lost by radiation (by difference), 1.9 per cent.

A study of the curves as given in Fig. 2 showing fuel consumption in the boiler room will give some idea of the fuel saving effected by utilizing this waste heat; however, it must be remembered that as yet we are utilizing only about 60 per cent of the waste heat available at the plant under normal working conditions. In all we

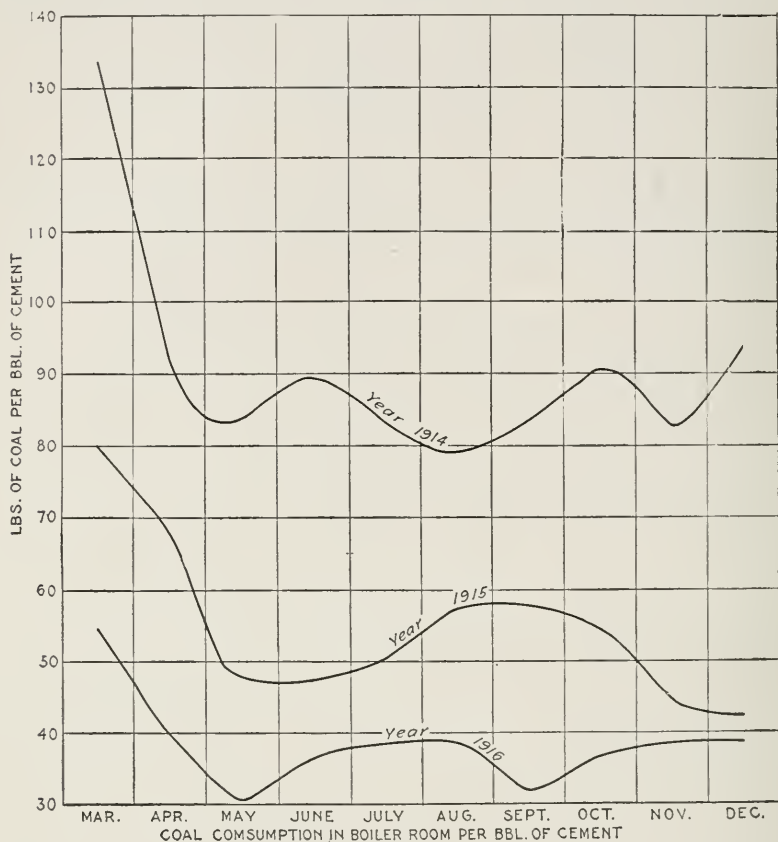


FIG. 2.

have six kilns, two, 100 by 7 feet; two, 125 by 8 feet; and two, 150 by 10 feet. But we have under erection a second boiler (similar to the first) that will be used in connection with the four smaller kilns. Before the installation of the boiler our coal consumption in the boiler room for 1914 averaged 91.7 pounds per barrel of cement. The waste heat boiler was put into service during May, 1915, with the result that our average coal consumption for 1915 was 57.6

pounds per barrel of cement. During 1916 the boiler was operated practically full time and our average fuel in the boiler room for the year was 40.2 pounds per barrel. Hence it can be readily seen that after the second boiler is put into service, very little power will be developed outside of the waste heat units, it being perhaps necessary to keep two stoker-fired boilers floating on the line for emergency.

As stated before, under the old way of kiln operation less than 40 per cent of the heat received by the kilns was actually utilized, but by using the hot clinker to heat the air for combustion, and the waste kiln gases to generate steam, our per cent of heat utilized has almost doubled, showing 67.2 per cent fuel efficiency in combined system of kilns and waste heat boiler, and this we hope to increase to 70 per cent by reclaiming a part of the heat now lost by radiation from the kiln shell, and it is but another step to reclaim a part of the heat now escaping from the stack of the waste heat boiler, or in other words our combustion efficiency will eventually compare very favorably with general boiler room efficiency.

SUMMARY

- Summing up in a general way, the gains that have been realized utilizing the waste heat, we may mention:

(a) The decrease in fuel required to burn a barrel of cement from approximately 110 pounds per barrel to less than 100 pounds, this being largely due to the preheating of the air for combustion by drawing it over the hot clinker and also in having the coal feed under absolute control.

(b) An increase of general efficiency of heat absorption from 37.6 per cent to 67.2 per cent of total heat supplied to kilns, the gain being shown in the boiler horse-power developed without an increase in fuel consumed in kilns per barrel.

(c) The recovery of at least one-half the dust that was formerly carried out the kiln stack.

(d) And last but not least, the solution of draft control on the kilns through the use of the large induced-draft fan. This alone is quite worth while, since cement engineers seldom agree as to size and shape of kiln stacks; but with the variable fan speed obtainable each authority can have just the draft that best suits his conditions.

DISCUSSION

President G. W. THOMPSON: Is there any discussion of this paper, gentlemen? The writer of the paper not being here, we cannot very well question him.

As a matter of interest in this country, my attention has been called to a certain smelting plant operating about 1910 or 1911, reverberatory furnaces, which are more or less intermittent in their operation. Each one of these furnaces is connected with a boiler and each one supplies enough steam to operate its own machinery, because it works with a forced draft, and furthermore furnishes power for the machinery for the treatment of the air in the plant. These boilers are all connected into a common header, and if a furnace is shut down that boiler is cut out from the general steam supply, and inasmuch as the furnaces are not all operating at their highest heat at the same time, the operation being more or less staggered, so to speak, there is a constant steam supply. It is only very occasionally that they have to take power from outside sources, when something goes a little wrong. It is a very interesting proposition and in these days of conservation, it is very interesting to see the extent to which the utilization of waste heat is carried.

Dr. JAMES S. PALMER: I can give the most remarkable illustration of this I ever saw. Years ago I was chief chemist of the Anaconda Smelter in Montana and the regular works engineer who was watching the utilization of heat reported that flue gases from the reverberatories were going up the stack at a temperature of nearly 800 degrees. Of course, these fumes at the reverberatory furnaces were highly acid and they queried whether it would be safe to do it. But they put up some boilers and they got enough heat from the reverberatory furnaces that was going to waste to produce 400 horse-power. Those furnaces were very much smaller than they are using now. I have not been able to follow this thing at all, but I remember one day when I was sent out to get samples when some of the furnaces were temporarily shut down and I scraped off from some of the tubes of the Sterling boilers materials which analyzed over 20 per cent NO_3 . It was so highly anhydrous that chemical action was going on. That seemed to run for months. I never heard they had any bad results or explosions from heating through the pipes there, and they got them from very highly acid fumes.

Mr. HARRY O. CHUTE: Mr. Chairman, I have some information

along that line in recent practice. In the reverberatory furnaces throughout the southwest, where oil is used, a ton of ore is smelted with a barrel of oil, and by the use of waste heat in boilers enough heat is developed to account for one-half a barrel of oil, so that 50 per cent of the heat of the oil is developed in smelting furnaces and 50 per cent is utilized in the waste heat boilers, and it is getting to be an almost universal custom in working the reverberatory furnaces in the West nowadays, to put waste heat boilers behind the smelter, and just as was found here, where a 280-horse-power boiler developed only 135 horse-power, so it is always found in waste heat boilers, that the boilers will not run to their rated capacity, and this is, of course, due to the fact that the waste gases do not reach them, with the high temperature of combustion, as would happen if the coal were burned directly under the boilers.

Mr. Moore told us a good deal yesterday about utilizing heat under waste heat boilers and everything he said there is applicable to other situations.

Mr. HUGH K. MOORE: Referring to the remarks just made and speaking of the waste heat from working different processes, one of the reasons for the lack of efficiency of a boiler put behind is this: That a whole lot of the heat which actually is caught in the ordinary boiler is the radiant heat from the fire. If you figure out what the theoretical temperature should be of the fire, and the heat which you actually get by putting in a pyrometer you will find there is a very great discrepancy, and that radiant heat is going right to the boiler, and tests which I have made have shown in many cases that the bottom shell of a tubular boiler will take two-thirds of the heat which a whole boiler takes.

We have several of those waste heat propositions. For instance in our caustic kettles in Berlin we put waste gases through waste heat boilers just for that purpose, and in the Burgess Mill we have done a lot of that, and we have made actual determinations, having first found the limit of error in such a determination, and have shown that the amount of radiant heat that actually goes into a boiler is something enormous. A person ordinarily thinks of the heat in a boiler coming through the gases, which is really a small part of the heat in a steam boiler.

Mr. RICHARD K. MEADE: Unfortunately I did not get up here during the early part of the discussion, but I might say that the subject of utilization of waste heat from the cement kiln gases is quite

an old one. It was first tried out in the Atlas Cement Company about twenty years ago. It failed there beyond a doubt. They at that time used simply the return tubular boiler. Later on, it was tried at the Cayuga Lake plant in New York State and there they used Sterling boilers and their results were very poor. The reason that they have obtained as good results as they have in these late installations is because they passed the gases through the boiler at a high velocity. Instead of using a draft of six-tenths of an inch of water in the stack as they would with a great draft of water, they are now using six inches of water draft which they are obtaining by means of a fan, and in all of the later installations of waste heat boilers that they have put in in our own cement plants and plants of that character where the gases are of a comparatively low temperature, they have used higher velocity.

RELATION BETWEEN EFFICIENCY OF REFRIGERATING PLANTS AND THE PURITY OF THEIR AMMONIA CHARGE

By F. W. FRERICHS

Read at the St. Louis Meeting, Dec. 5, 1917

When I visited the Loan collection of scientific apparatus exhibited in Kensington Museum, London, England, in 1876, I saw for the first time ice machines on exhibit. They were small affairs, operated with ether, carbon dioxide, sulfur dioxide, or with ammonia by the absorption process.

In the years immediately following, Linde published his classical investigations on the Ammonia Compression Ice Machine, laying thereby the foundation for that type of refrigerating plants which at present is predominant here and abroad.

In 1880, when I arrived in the United States, artificial refrigeration was still in its infancy. But even at that time the superiority of ammonia as a refrigerating agent for larger plants, in preference to other agents, was well established.

Liquefied ammonia gas, however, had not yet become an article of commerce, and the compression ice machines at that time had an attachment by which liquefied ammonia gas could be made from aqua ammonia. Aqua ammonia of great purity was not available and the quality of liquefied ammonia gas as made by non-chemists with simple apparatus in the ice plant left much to be desired.

In a paper read before this Institute on the occasion of its first annual meeting, I gave a full account of the methods of analysis and the purity of liquefied ammonia gas up to 1908; and from this account it would seem that in early times 2 per cent impurity or even more was quite the rule. But in those times the efficiency of refrigerating plants was low. They were largely confined to wort cooling and to cooling of storage rooms in breweries where considerations other than economy were paramount. Only when refrigerating machinery was utilized for making ice in competition with natural ice was greater efficiency demanded, and this called for purer ammonia.

Refrigeration is not a chemical industry, and for that reason chemists, as a rule, are not familiar with the details of ice plants. But the importance of chemical purity of the refrigerating agent cannot be fully understood without reference to some details of the plant in which it is used, and for this reason a few words would seem justified to explain the function of those parts of the apparatus which have a bearing on the action of ammonia in ice machines. If these are well understood, the importance of the purity of the ammonia charge will become apparent, and will be easily appreciated.

In utilizing ammonia, the latent heat required for evaporation of liquid ammonia is employed for the production of "cold."

Liquid ammonia has a boiling point of minus 28° F. at atmospheric pressure. Its latent heat of evaporation at 0° F. is about 555 B.T.U., and this heat is readily extracted from surrounding bodies having a higher temperature than -28° F., thus producing "cold," which by suitable apparatus may be utilized for the production of ice or for refrigeration.

The general arrangement of a refrigerating plant is such, that liquid anhydrous ammonia is evaporated at a low pressure and a corresponding low temperature in a closed vessel, which is submerged in a medium like brine or air. In evaporating at low temperature, the ammonia extracts heat from this medium, thereby lowering its temperature. The resulting ammonia vapors are again reduced to the liquid state by applying pressure and subsequent cooling in a condenser, and the liquid anhydrous ammonia is returned to the cycle of operations.

Refrigeration by ammonia is therefore a physical process and in theory the chemical composition of the ammonia in the cycle of operations remains unchanged. The transformation of ammonia from the liquid to the gaseous state and vice versa can go on indefinitely and theoretically a given amount of ammonia can produce an infinite amount of "cold."

Any set of apparatus constituting a refrigerating plant using ammonia for an agent includes, therefore, a device in which liquid ammonia is evaporated and a device to reduce ammonia from the gaseous to the liquid state. The first operation, as a rule, takes place in a pipe-coil which is submerged in the medium which is to be cooled. The second operation can be carried out in different ways, and from the method employed, refrigeration plants are classified as absorption or compression plants.

In absorption machines the ammonia gas is absorbed in cold, weak aqua ammonia to make strong aqua ammonia of about 30 to 35 per cent. This operation is carried out in the absorber. The resulting strong aqua ammonia is forced by a pump into the retort or boiler to be heated to about 150°C ., whereby it splits into weak aqua ammonia, 15 to 18 per cent, and hot ammonia gas standing under a pressure of 150 to 250 lbs.

The hot gas under this high pressure is led into the condenser to be cooled and thereby liquefied, producing in good plants liquid ammonia of 95 to 98 per cent purity, the balance being water, which had evaporated with the ammonia. The weak aqua ammonia is returned to the absorber.

In compression machines, the ammonia gas coming from the evaporating or freezing coil, is taken by suction into the ammonia pump, whereupon it is compressed to 150 to 250 lbs. pressure per sq. in.; the gas, hot from compression, is delivered to the cooler or condenser to be liquefied to ammonia of approximately 100 per cent purity, which is to be delivered again to the freezing coil, thus completing the cycle of operation.

Comparing the principles involved in absorption and compression machines, it is apparent that apparatus in which evaporation of liquid ammonia takes place at low temperature and low pressure, and the condenser or cooler in which hot ammonia gas of high pressure is reduced to the liquid state, are alike for both types of refrigerating machines. The expansion valve between the two apparatus and the valves in the pump separate the high-pressure side from the low-pressure side of the machine.

In compression machines the ammonia pump handles ammonia in the gaseous state. The pump is large on account of the great volume of ammonia gas, and its suction side has the same function as the absorber in absorption machines. The compression side has the same function as the aqua ammonia pump and the retort or boiler in absorption machines combined, and it delivers ammonia gas under high pressure to the condenser or cooler. In absorption machines the ammonia pump is comparatively small, since it handles ammonia in the liquid state, viz., in the form of aqua ammonia, which has a smaller volume than the equivalent amount of ammonia gas. The pump operates on cold aqua ammonia and does not require lubrication of the pistons.

In compression plants the ammonia pump is large, operates

on hot ammonia gas, and requires generous lubrication of cylinder pistons. Therefore, in compression machines, the lubricants require serious attention.

The arrangement of the fundamental apparatus in both types of machine is illustrated by the diagrams Figs. 1 and 2.

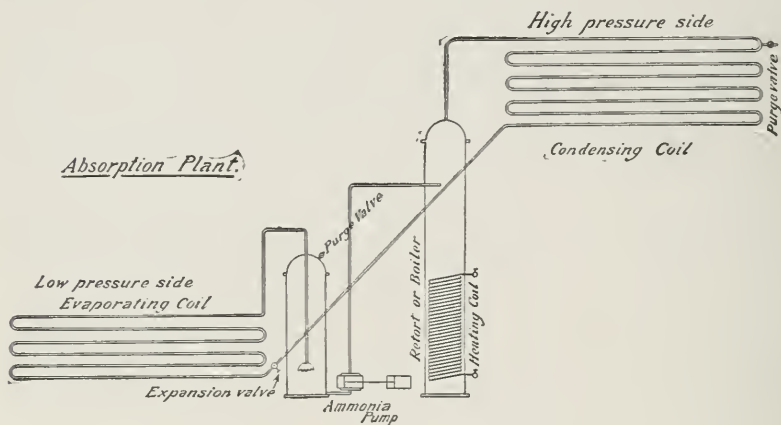


FIG. 1.

The object of both types of plant is to abstract heat from the low pressure or evaporating side and to deposit the same heat at the high pressure or condenser side. This transfer is accomplished by evaporating liquid ammonia at low temperatures, subsequently

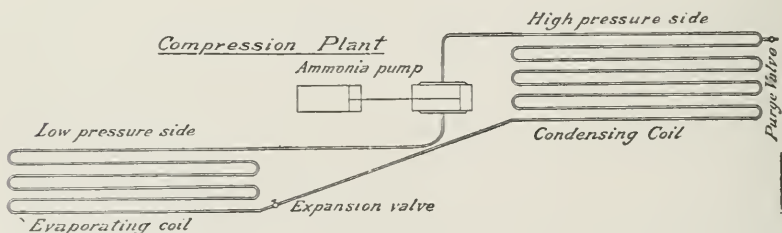


FIG. 2.

compressing the resulting ammonia vapors either by application of heat in the retort of absorption machines, or by application of power in compression plants, and to deposit the heat which was extracted at the low-pressure side in the condenser on the high-

pressure side, whence it is carried off by cooling water which runs through the condenser.

The amount of heat used in the retort of an absorption machine or the amount of power consumed in a compression plant multiplied by a constant is a measure of the amount of refrigeration actually produced. The value of this constant is the product of many factors, one of which is the free and ready evaporation and condensation of ammonia in the machine. All other conditions being equal, the evaporation and condensation of liquid ammonia goes on most freely if the ammonia is pure. If it contains substances either in suspension or in solution, which retard evaporation or which cause ammonia to boil only in a superheated condition, or which retard the transmission of heat to the ammonia, then the efficiency of the machine is impaired. For this reason ammonia of high purity will produce better results than impure ammonia.

Many impurities which retard evaporation are soluble in ammonia and are less volatile than liquefied ammonia gas. For this reason they may be detected by the evaporation test. An account of this test was given in an earlier paper (*Transactions* I, page 133). But there are many substances less volatile than ammonia, which are harmless and which do not impair the speed of evaporation, and yet show up in the evaporation test. To distinguish between harmful and harmless impurities in this regard, the apparatus shown in Fig. 3 was used to measure the time of evaporation of a definite quantity of liquid ammonia under constant conditions. The apparatus is made of glass and consists of a cylindrical evaporating vessel, *A*, graduated on its side and having at its lower end a narrow tube, *B*, in which liquid residues from evaporation may accumulate. The upper part of *A* is drawn out to a smaller cylindrical part, *C*, with tube *D* inserted which serves to connect the apparatus with the nozzle of the test valve on the ammonia shipping cylinder. *E* is an outlet tube for discharging ammonia vapors coming from the apparatus. *A* is surrounded by jacket *F*, which is joined to tube *B*, and a piece of sheet rubber having a round opening in the center is slipped over tube *C* and is tied over the upper rim of jacket *F* to make an air-tight connection. The air between *A* and *F* must be dry. The lower part of tube *B* is surrounded by an evacuated bulb, *H*, and the entire apparatus is set in a bath of a 20 per cent solution of calcium chloride, *I*, provided with agitator,

K, and thermometer, *L*, which serve to maintain a uniform temperature in the apparatus. The calcium chloride solution is con-

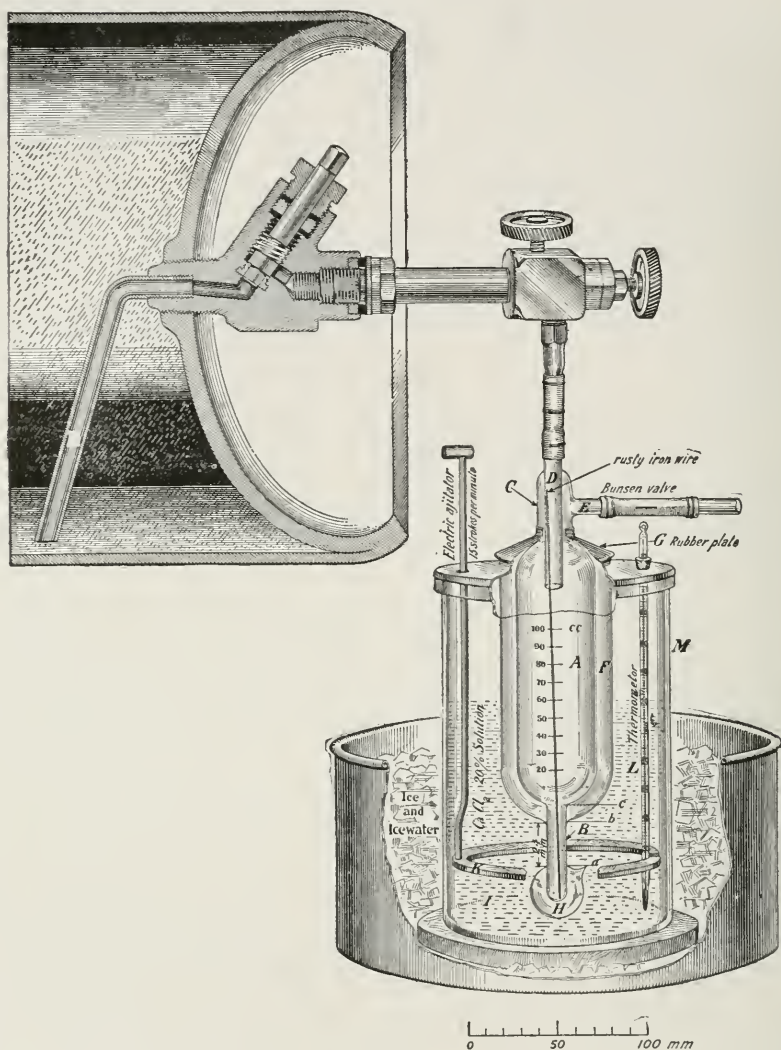


FIG. 3.

tained in a glass jar, *M*, which stands in a bath of ice water and crushed ice.

In evaporating, the ammonia takes heat from the solution of calcium chloride, which in turn takes heat from the melting ice. The object of the apparatus is to make the transfer of heat to the ammonia uniform, in order to make time the measure of evaporation. Dry air in jacket *F* and the vacuum in bulb *H* being bad conductors, all heat must travel through the glass walls of tube *B* between *a* and *b*, which represents the heating surface of the apparatus. Tube *B* extends into bulb *H* to serve as the receptacle for residues of evaporation, which may accumulate in this place, without reducing the area of the heating surface of the apparatus.

The operation of the apparatus is self-evident. By operating the valves on the ammonia cylinder, the apparatus is filled to the mark 100 c.c., whereupon evaporation of the ammonia takes place regulated by the amount of heat which travels from the calcium chloride solution through the walls of tube *B* to the ammonia.

When the ammonia in *A* is evaporated to point *c*, the time of evaporation is noted, together with the temperature of the calcium chloride bath, whereupon a new charge of ammonia is admitted by filling the apparatus up to the 100 mark, and any number of additional charges of liquid ammonia may be evaporated. In repeating the operation, the impurities in the ammonia are concentrated and the time necessary for the evaporation of successive portions is a measure of the increasing amounts of impurities in the ammonia.

Tables I and II give the results of two series of experiments, the one of which is made with pure ammonia, similar to quality *B* in Table III on page 20; the other with less pure ammonia, resembling in composition quality *H* in the same table.

Comparing the values in the two tables, it would seem that the velocity of evaporation of liquid ammonia is not affected by the presence of such small amounts of impurities as are contained in sample *H*. However, the velocity of evaporation decreases rapidly as soon as the oily material, which separates in increasing quantities from the ammonia in successive tests, increases in volume, covering part of the heating surface of the apparatus, and the table shows also that by the time the entire heating surface is covered with oily material the velocity of evaporation is reduced by 50 per cent.

Among the substances not soluble in liquid ammonia but always present in compression plants, is lubricating oil from the compressor. Its retarding action rests in its low coefficient of conductivity for

heat. If it enters the condenser it coats the inside of the ammonia pipe, but owing to the high temperature the oil is very liquid and the coating is thin. Nevertheless, the thin coating of oil in the condenser retards the transference of heat, but the amount of retardation is small, and can be overcome by increasing the pressure on the discharge side of the ammonia pump. If the plant is operated at 200 lbs. pressure, 5 lbs. of which is used for overcoming the retardation caused by the coating of oil, then the loss of efficiency for the sake of argument may be assumed to be $2\frac{1}{2}$ per cent.

Conditions in the evaporating coil are widely different. The evaporating coil is cold, the oil is thick, the coating of the walls inside the pipes is heavy, and consequently the retardation is large. If in this place the pressure is 15 lbs. per sq. in., and if it must be reduced by 5 lbs. to overcome the retardation in the travel of heat, then the loss of efficiency must be counted as $33\frac{1}{3}$ per cent instead of $2\frac{1}{2}$ per cent, as was the case in the condenser. For this reason the evaporating coil must be kept free of lubricating oil.

The evaporated ammonia is withdrawn from the freezing coil by the absorber in absorption machines, or by the ammonia pump in compression plants. Here again the efficiency is greatest if the ammonia is pure. If the ammonia is contaminated with gases, which cannot be absorbed by water, then these gases will accumulate in the absorber in the case of absorption machines and cause pressure, which prevents the ready flow of ammonia gas towards the absorber, whereby the efficiency of the plant is reduced.

In the case of compression machines, any gases not ammonia will fill space in the cylinder of the ammonia pump, and will reduce the efficiency of the pump in direct proportion to the volume of such gases present. If the ammonia gas contains 10 per cent of such gases, then the efficiency of the pump will be reduced by 10 per cent.

More serious is the presence of non-condensing gases in ammonia at the compression side of the machine. In both absorption and compression plants, the gas under high pressure enters the condenser to be liquefied. Liquefaction depends upon the pressure and temperature in the condenser. The temperature being largely invariable, since it is dependent upon the temperature of the cooling water, the efficiency of a given plant depends largely upon the pressure of the ammonia gas alone.

TABLE I.—EVAPORATING TEST OF LIQUID ANHYDROUS AMMONIA
PURITY SIMILAR TO SAMPLE B IN TABLE III, P. 20

1914.	TEMPERATURE, DEG. F. AT START.			100 c.c. Evapo- rated. Duration of Test, Minutes.	TEMPERATURE, DEG. F. AT END.			Calcu- lated Time of Evapo- ration at 15 Lb. Pressure. 15 ⁷ Brine, Minutes.
	Air.*	Water.	Brine.		Brine.	Water.	Air.*	
July 21.....	90	38	42	130	28	38	90	
	90	38	28	140	28	40	90	570
	90	40	28	135	26	38	90	540
	90	38	26	140	26	38	90	549
Average..	.....	.....	.....	.....	.....	.....	.....	553
July 22.....	95	42	46	125	30	42	95	
	95	42	30	135	28	38	95	559
	95	38	28	140	28	38	95	570
	95	38	28	135	28	38	95	549
Average..	.....	.....	.....	.....	.....	.....	.....	559
July 23.....	95	40	46	125	30	40	95	
	95	40	30	130	28	40	95	538
	95	40	28	140	28	36	95	570
	95	36	28	140	28	36	95	570
Average..	.....	.....	.....	.....	.....	.....	.....	559
July 24.....	97	42	48	125	28	36	97	
	97	36	28	135	26	34	97	540
	97	34	26	140	26	34	97	549
	97	34	26	140	26	34	97	549
Average..	.....	.....	.....	.....	.....	.....	.....	546
Grand av.	.....	.....	.....	.....	.....	.....	.....	554
Probable error.....	.....	.....	.....	±2.5	.....	.....	.....	±10

NOTE.—No residue accumulated in the lower part of tube B, therefore any number of evaporations of new quantities of ammonia could be carried out with the same results.

Evaporation of the first sample on every day was not considered, because the high temperature of brine made results irregular.

* Average temperature of air.

TABLE II.—EVAPORATING TEST OF LIQUID ANHYDROUS AMMONIA
PURITY SIMILAR TO SAMPLE *H* IN TABLE III, P. 20

1914.	TEMPERATURE, DEG. F., AT START.			100 c.c. Evaporated. Duration of Test, Minutes.	TEMPERATURE, DEG. F., AT END.			Calculated Time of Evaporation at 15 Lb. Pressure, 15° F., Minutes.
	Air.*	Water.	Brine.		Brine.	Water.	Air.*	
Aug. 15.	88	42	52	130	28	38	88	
	88	38	28	150	26	36	88	540
	88	36	26	150	26	36	88	520
Aug. 17.	94	42	50	135	28	38	94	
	94	38	28	150	28	38	94	560
	94	38	28	150	26	34	94	540
	94	34	26	150	26	34	94	520
Aug. 18.	95	40	50	140	28	36	95	
	95	36	28	150	28	36	95	560
	95	36	28	150	28	34	95	560
	95	34	28	150	28	34	95	560
Aug. 19.	93	40	50	140	28	36	93	
	93	36	28	150	28	36	93	560
	93	36	28	150	28	36	93	560
	93	36	28	155	28	36	93	579
Average	.....	.....	.....	.....	.....	.....	.....	550
Oily liquid at <i>a</i> , Fig. 3.								
Aug. 20.	88	48	54	140	28	38	88	
	88	38	28	155	28	36	88	579
	88	36	28	155	28	36	88	579
	88	36	28	155	28	34	88	579
Aug. 21.	90	50	58	140	28	36	90	
	90	36	28	155	28	36	90	579
	90	36	28	160	28	36	90	597
	90	36	28	160	28	36	90	597
Aug. 24.	75	48	58	155	28	38	75	
	75	38	28	195	28	36	75	
	75	36	28	200	28	36	75	747
Aug. 25.	70	50	58	205	28	36	70	
	70	36	28	205	28	36	70	765
Aug. 26.	81	40	52	205	28	36	81	
	81	36	28	220	28	36	81	821
Aug. 27.	75	50	58	225	28	36	75	
	75	36	28	235	28	36	75	877
Aug. 28.	70	40	48	250	28	36	70	
	70	36	28	260	28	36	70	971
Aug. 29. ....	.....	44	50	265	38	36	.....	
	.....	36	28	270	28	36	.....	1008
Aug. 31. ....	.....	44	50	260	30	36	.....	
	.....	36	30	275	30	36	.....	1063
Sept. 1. ....	.....	42	52	270	30	34	.....	
	.....	34	30	285	30	36	.....	1102
Oily liquid at <i>b</i> , Fig. 3.								
Sept. 2. ....	.....	46	54	280	30	34	.....	
	.....	34	30	295	30	34	.....	1141
Sept. 3. ....	.....	36	38	285	30	36	.....	
	.....	36	30	295	30	36	.....	1141
Sept. 5. ....	.....	50	54	290	30	36	.....	
	.....	36	30	295	30	36	.....	1141
Probable error. ....	.....	.....	.....	± 2.5	.....	.....	.....	± 10

* Average temperature of air.

Pure ammonia gas condenses to liquid ammonia at lowest pressure at a given temperature. If the ammonia gas is contaminated with gases of a non-condensing nature then the pressure necessary for condensation of the ammonia in the gas mixture is increased, according to well-known physical laws. The increase of pressure is in direct proportion to the amount of non-condensing gases present. If the ratio of ammonia to other gases is 1 to 1, then twice as much pressure is required for its condensation as for the condensation of pure ammonia.

This applies both to absorption and compression machines. It becomes serious if the space which is occupied by the gases in the condenser is small. Double pipe condensers, which are mostly used, have a very small condensing space, measuring at an average 12 cu. in. per ft. of pipe. The ammonia in a gas mixture forced into a condenser is liquefied and is withdrawn while the contaminating non-condensing gases remain, gradually filling the condenser in cumulative action and paralyzing its efficiency. For this reason ammonia of high purity will produce superior results.

The non-condensing gases mixed with ammonia may be air, and in this case they are easy to detect. An apparatus for measuring them is published in Vol. VI, p. 214, of our *Transactions*. But there may be other impurities in ammonia, which liquid in themselves may produce non-condensing gases in ice machines, and many of these substances are difficult to detect by analysis. Therefore the consumer must largely rely upon the reputation of the ammonia manufacturer who stands for the quality of his goods.

There is another source from which non-condensing gases may develop in compression machines, and it must be well understood that not in all cases is the quality of ammonia responsible for the presence of non-condensing gases in the machine. The oil used for lubricating the compressor mixes intimately with the ammonia and if it contains substances, which at temperatures prevailing in the machine develop permanent gases, then these constituents of the oil act in the same manner as if they were brought in with the ammonia charge. Fortunately most oil is good in this respect; and particularly the cheaper grades of compressor oil give good satisfaction. However, there is oil on the market which is undesirable, and operators of ice machines do well to make sure of the good quality of the oil they use in their machines.

A simple apparatus for testing oil in this respect is represented by Fig. 4. It is operated as follows:

With the stopper removed, the bulb tube is filled entirely with the oil, which is to undergo the test, whereupon the stopper is firmly inserted and the excess oil is removed from the funnel over the stopper. Upon heating in a metal bath, undesirable oils will develop gases which will accumulate under the stopper, while an equivalent volume of oil is forced through the capillary tube into the funnel over the stopper and the volume of gas may be measured by the graduation on the tube.

If non-condensing gases accumulate in the machine, it becomes necessary to remove them and the operation of doing this is called purging.

Purging is generally done by opening a small valve on the top of the condenser, or absorber, or both. These gases which always contain a large proportion of ammonia may be led by a tube under water whereby ammonia is absorbed, the permanent gases rising in bubbles to the surface of the water. If no bubbles form, all the non-condensing gases are removed, and purging is completed. Another way of purging is to let the gases escape into the air and ignite them by a torch, in which case they burn with a luminous flame which dies out as soon as pure ammonia flows from the orifice. With pure ammonia in the machine, purging may be done at long intervals of time, while with impure ammonia daily purging becomes a necessity.

There is finally a class of impurities found in ammonia which causes corrosion of iron from which ice machines are made. This occurs more frequently in absorption plants, where corrosion often destroys parts of machinery, causing leaks, and subsequent loss of ammonia during operation.

Acetic acid, acetonitrile, and similar compounds belong to this class of impurities, and they are frequently found in aqua ammonia. A small amount of acetic acid can corrode large quantities of iron by hydrolysis, since the acid always is regenerated. The chemical action on parts of apparatus is illustrated by two tubes represented in Figs. 5 and 5a. Both tubes were used for four years in two absorbers, the one in pure, the other in impure, aqua ammonia. The one has lost hardly any of its weight, while the other is corroded to a thin shell.

In absorption machines the heating coils in the retort are most seriously affected by impure ammonia.

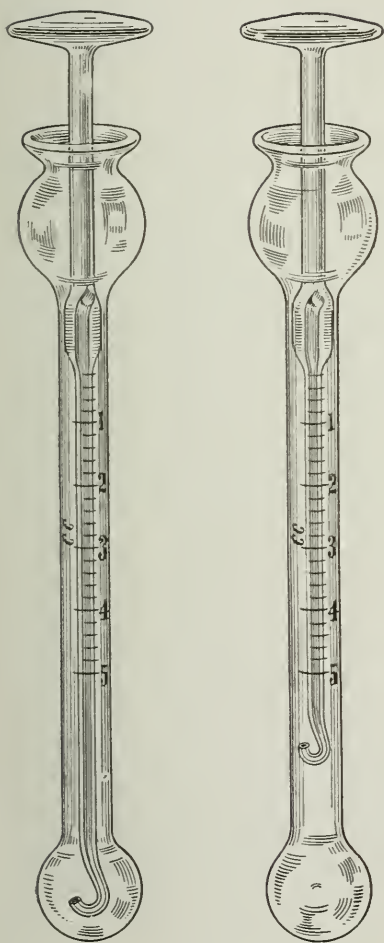


FIG. 4.

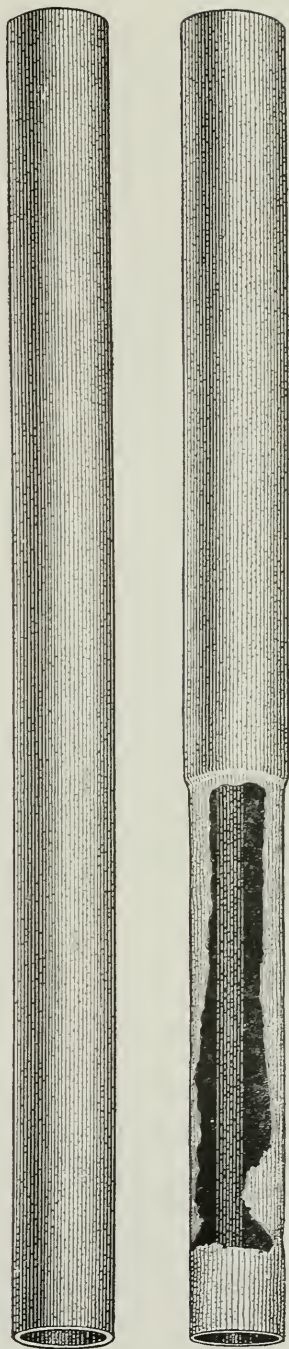


FIG. 5.

FIG. 5a.

Fig. 6 represents the lower part of a retort containing a double heating coil. The coil is made from $1\frac{1}{4}$ -in. extra strong iron pipe, and weighs about 1200 lbs. If used with pure aqua ammonia, it will last many years, while with impure ammonia frequent renewal becomes imperative. I hold records about coils of this particular

size, which in a single year lost as much as 100 lbs. of their weight by corrosion if used with impure ammonia, and I have records of other coils of the same size which were used for as much as 10 years with pure ammonia under the same conditions as the first-mentioned coils and which lost less than 5 lbs. of their original weight.

How seriously the efficiency of an ice plant can be affected by impure ammonia is strikingly demonstrated by the results which were obtained in the operation of two new and identical absorption ice machines, operated in parallel and independently of one another by the same steam plant, by condensing water of the same temperature, and by the same set of engineers, but charged with an equal quantity of ammonia of different purity. Both qualities of ammonia were goods offered in the regular market and were purchased by the manufacturer of the two ice machines for the purpose of making a comparative test of the

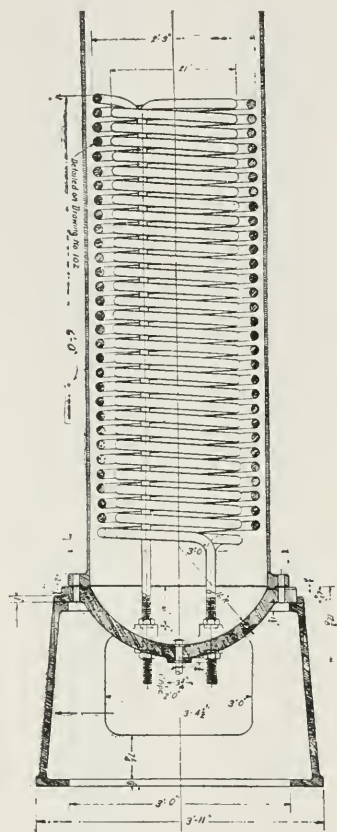


FIG. 6.

ammonia. The operations were conducted under the direction of the manufacturer of the ice machines and by the proprietors of the plant, who were disinterested parties. Each of the two ice machines had a capacity of 50 tons and there was an independent ice tank for each machine. The test was run over a period of almost 17 months, beginning June 6, 1914, and terminating October 31, 1915.

The first charge of each machine consisted of 16,500 lbs. aqua ammonia, 26° Bé. and 3855 lbs. liquid anhydrous ammonia. During the 17 months of operation 375 lbs. aqua ammonia 26° Bé. and 775 lbs. liquid anhydrous ammonia were added to replenish the charge in plant No. 1, and on Oct. 31, 1915, after 17 months' operation, the charge was approximately of the same strength as at the beginning of the test run. The machine was operated 24 hrs. per day except between seasons, when it was run in day time only and in winter, when it was shut down. Ice was drawn at the rate of 55 tons per day during about 8 months and refrigeration was supplied to the ice-storage room estimated to be equivalent to 3 tons of ice per 24 hrs. in the warm season of the year. The plant ran regularly about 15 per cent over rated capacity. A total of 15,862 tons of ice was pulled, and counting the refrigerating done as equivalent to 1000 tons, 16,862 tons of ice were produced in 17 months at an expense for ammonia amounting to 1.27 cents per ton of ice. Nineteen tons of ice were made for every pound of ammonia lost in operating the plant.

No serious leaks were observed in the plant. Small quantities of permanent gases were burned off during the first weeks of operation, giving a flame about 3 in. long from a $\frac{3}{8}$ -in. pipe. No gas was purged off during the following 4 months and in the second summer a flame of only about $\frac{1}{2}$ in. length could be burned from the purge tube at intervals of time and then only for a few minutes.

A sample of aqua ammonia drawn from the machine after 17 months' run was clear as water and it is believed that no corrosion whatever has taken place inside the plant. This, however, can only be confirmed by opening the apparatus, which will probably not be necessary for several years to come.

The result of this run is remarkable if it is compared with the result in plant No. 2. This plant was started June 22, 1914, 18 days later than plant No. 1. With the same quantity of ammonia, bought from a different manufacturer and used for the initial charge, plant No. 2 could produce only 42 to 44 tons of ice while plant No. 1 had made 57 tons. Upon the addition of 1000 lbs. anhydrous ammonia, 50 tons of ice could be made per day in No. 2.

From June 22, 1914, to November 1, 1915, that is, in about $16\frac{1}{4}$ months, 13,183 lbs. aqua ammonia 26° Bé. and 3484 lbs. anhy-

drous ammonia were used in addition to the initial charge, and at the end of the period the ammonia charge in the machine was about 1000 lbs. short on ammonia. 11,308 tons of ice had been made during the period and the cost of ammonia per ton of ice was 15.16 cents as against 1.27 cents in plant No. 1. One and one-third tons of ice were made for every pound of ammonia lost in operating the plant.

Serious leaks were observed after a few weeks' operation in the screw connections of the pipes and condensers, caused by corrosive action of the ammonia. Large quantities of permanent gases were burned off daily during the entire period of operation, giving a flame of as much as 3 in. diameter, and over 24 in. long, and this flame would burn from 20 to 30 min. at a time. The excessive consumption of ammonia was caused by leaks and by purging.

A sample of aqua ammonia drawn from the machine after 16 months' operation was dark and dirty, and no doubt considerable corrosion had taken place inside the apparatus.

Plant No. 1 had made during the test-period an equivalent to 16,862 tons of ice, while plant No. 2 made 11,308 tons, a deficiency of 33 per cent, and this deficiency must be attributed alone to the difference in quality of the ammonia charge.

The consumption of coal in plant No. 1 was ascertained to be 1 ton of Illinois coal to eight tons of ice, while in plant No. 2 only $5\frac{1}{2}$ tons of ice were made per ton of coal, consumed under the boiler.

Similar differences in efficiency were experienced in many plants, which led to the belief that the quality of the ammonia charge had an important bearing upon the operation of ice plants. There were no methods of analysis known to be delicate enough for the purpose of differentiating between the quality of different brands of ammonia, and it seemed to be of sufficient importance to have methods of analysis developed even at great cost for the best of the refrigerating industry. Upon the request of the American Association of Refrigeration, Congress appropriated \$30,000 to be put to the credit of the Bureau of Standards, which sum was to be used for the development of methods of analysis of commercial ammonia and for the determination of physical constants of refrigeration.

The composition and testing of commercial liquid ammonia was admirably investigated by E. C. McKelvy and C. S. Taylor, both of the United States Bureau of Standards, Washington, D. C.,

by experiments equal in accuracy to determinations of atomic weights.

A progress report on the result of 2 years' work was presented at the twelfth annual meeting of the American Society of Refrigerating Engineers in December, 1916, and published in their journal for March, 1917.

The report describes in detail methods of sampling and methods of analysis for the quantitative determination of, first, non-condensing gases; second, residue on evaporation; third, volatile impurities containing carbon; fourth, water; fifth, pyridine; sixth, acetonitril and ammonium acetate, and seventh, direct determination of ammonia.

McKelvy and Taylor made by these methods a series of comparative tests on eleven samples of liquid anhydrous ammonia made by ten different manufacturers and tabulated the results. The eleven samples were marked by letters of the alphabet from *A* to *S*. Samples *A* to *H* represented eight standard American brands provided in 50- to 150-lb. cylinders. They were obtained either by purchase in the open market, or by purchase or donation from manufacturers, and are believed to represent fairly well the material now used in the refrigerating industry. Samples *K*, *L*, and *LL* were of German origin, *L* having been purchased in 1906. Sample *M* was an American product purchased in 1907. Sample *S* was prepared from sample *B* by several fractional distillations the first of which was made from metallic sodium.

The results of the comparative tests are given in Table III, opposite the letter indicating the origin of the sample. The column headings show the nature of the tests and the manner of expressing the results.

As to the limit of accuracy of the figures given in the table, it was found that in the case of volatile carbon compounds the results were too low. Fifty-eight grams of pure ammonia, mixed with 3 mg. acetonitrile yielded 95 per cent of the carbon in the combustion test, while 58 gs. of ammonia mixed with 15 mg. acetonitrile yielded only 67 per cent of the calculated amount of carbon dioxide, owing to incomplete combustion in the experiment. For this reason, the values given in the table for samples *B* and *K* are fairly correct, while the amounts of carbon dioxide obtained from other samples were much too low, probably by 40 to 100 per cent. In the case of pyridine, the limit of accuracy was found to be 1 in 100,000,

TABLE III.—COMPOSITION OF LIQUID ANHYDROUS AMMONIAS

Sample	NON-CONDENSING GAS.					Residue on Evapora- tion.	Volatile C Com- pounds.	WATER.	
	In Liquid C.c. per 100 g.	In Gas C.c. per 100 g.	Composition.						
Marked			N ₂ %	O ₂ %	H ₂ %	By weight (%)	g. CO ₂ per 100g. NH ₃ .	Method KOH (%)	Method CaC ₂ (%)
A	7		69.1	30.9	0.0	0.012 <i>h</i>	0.019	0.006	0.013
		26	86.7	13.3	0.0	0.007 <i>l</i>		0.001	
B	4		70.8	29.2	0.0	0.009 <i>h</i>	0.002	0.007	0.042
		9	70.0	30.0	0.0	0.011 <i>l</i>		0.008	
C	6		70.3	29.7	0.0	0.008 <i>h</i>	0.051	0.007	0.030
		8	69.4	30.6	0.0	0.008 <i>l</i>		0.005	
D	6		68.4	31.6	0.0	0.014 <i>h</i>	0.029	0.006	0.030
		12	72.6	27.4	0.0	0.017 <i>l</i>		0.004	
E	6		65.0	35.0	0.0	0.011 <i>h</i>	0.019	0.006	0.030
		11	74.0	26.0	0.0	0.010 <i>l</i>		0.006	
F	15		67.0	28.7	4.0	0.015 <i>h</i>	0.061	.....	0.026
		8032	80.1	19.9	0.0	0.022 <i>l</i>			
G	6		70.0	27.0	3.0	0.025 <i>h</i>	0.032	0.007	0.026
		9	68.0	26.0	6.0	0.100 <i>l</i>		0.009	
H	6		66.7	33.3	0.0	0.062 <i>h</i>	0.902	0.010	0.027
		11	66.7	33.3	0.0	0.134 <i>l</i>		0.010	
K	7		69.0	31.0	trace	0.276 <i>h</i>	0.004	0.011	0.80
		19	80.0	20.0	trace	0.300 <i>l</i>		0.032	
L	9		77.5	22.5	0.0	0.533 <i>h</i>	0.497	0.041	0.50
		5680	99.4	0.6	trace	0.540 <i>l</i>		0.069	
LL	15		79.0	21.0	0.0	0.318 <i>h</i>	0.103	0.053	0.33
		1870	99.3	0.7	0.0	0.230 <i>l</i>		0.040	
M						0.040 <i>h</i>	0.014		
						0.051 <i>l</i>	0.011		
S						0.000	0.000		0.008

h Evaporation at room temperature. *l* Evaporation at low temperature.

and for acetonitril and ammonium acetate quantities less than 5 in 100,000 could not be detected.

In addition to the results in the table, McKelvy and Taylor point out the following data of interest:

Sample *F* contained a trace of pyridine and sample *H* 0.02 per cent. The German samples *L* and *LL* contained 0.015 per cent and 0.005 per cent respectively. All others contained less than 0.001 per cent.

In the samples showing a low residue on evaporation (*A* to *E*), the residue consisted of a reddish film hardly visible. For the other samples at most a brownish drop of oily liquid was left, and only for samples *K*, *L*, and *LL* could the volume of the results have been measured. The percentage of iron oxide in the residue was greater the smaller the amount of residue in the sample.

Sample *F* contained 0.005 per cent ammonium acetate or acetate forming substance, and sample *L*, a trace. All others contained less than 0.005 per cent.

The results of the combustion tests showed a marked difference in the various samples, but in practically all of the tests McKelvy and Taylor observed that no carbon dioxide appeared in the absorber until at least 95 per cent of the liquid had evaporated.

In making this observation, the Bureau of Standards in 1916 disclosed the fact that small quantities of volatile carbon compound can be concentrated into a small volume of liquid anhydrous ammonia by fractional distillation. The Badische Company observed the same fact and patented its invention in 1913. The same process was discovered and put into operation in 1892 in these works and has been in successful operation ever since. While inspecting our works this afternoon you will have an opportunity of seeing the first apparatus used in 1892 and the present plant comprising 5 compressors and 3 stills capable of redistilling 25,000 lbs. of liquid anhydrous ammonia per day of 24 hrs. The product corresponds in quality to sample *B* in the table, the volatile carbon compounds of which are so small that by burning 100 grams ammonia only 0.002 g. carbon dioxide could be obtained, which indicates that less than 0.001 per cent volatile carbon compounds could have been in the ammonia.

Sample *K* in the table, which comes nearest to *B*, was ammonia made in Germany by the Haber process and was evidently redis-

tilled, since the Badische holds a patent for purifying ammonia from the Haber process by fractional distillation.

The importance of this investigation is emphasized if I state that in the test run with the two 50-ton machines described in this paper, plant No. 1 was charged with ammonia which in quality was equal to sample *B* in the table. The aqua ammonia for the prime charge of this machine was also made by saturating pure distilled water with ammonia of purity *B*.

Plant No. 2 was charged with aqua ammonia of unknown purity. The same brand, however, has given good satisfaction in other instances. But I have reason to believe that the liquid anhydrous ammonia in this charge was similar in quality to sample *H*, and from this the conclusion might be drawn that the difference in efficiency of the two plants was caused by the difference in purity of the ammonia charges and more particularly by the presence of volatile carbon compounds in the ammonia.

It is to be hoped that this progress report of the Bureau of Standards may soon be followed up with a complete account. The remaining part of the report will include an investigation and analysis of aqua ammonia, a most difficult problem, and at the same time, a problem of the greatest importance for the operation of absorption ice machines. At the present we possess no method of analysis sensitive enough to ascertain small quantities of impurities in aqua ammonia, and enormous sums of money are constantly being lost in the operation of absorption ice machines on account of impure ammonia.

The only way to minimize these losses at the present time would seem to be in using liquid anhydrous ammonia of known purity and pure distilled water for charging absorption plants. But attention should be paid to the quality of distilled water, which rarely is made of sufficient purity to answer this purpose. Here in St. Louis we are fortunate to have a supply of city water which upon a single distillation yields an excellent product for use in making aqua ammonia. In the city water plant, Missouri River water is first purified by sedimentation, after the suspended matter has been coagulated by sulphate iron and lime. A subsequent filtration by sand filters removes the last suspended matter and oxidation with chlorine removes bacteria.

From water obtained by distillation of St. Louis city water, and liquid anhydrous ammonia of purity *B*, my company is manufac-

turing pure aqua ammonia for use in absorption ice machines, and aqua ammonia used in the test run in Plant No. 1, which was described before, was aqua ammonia of this purity.

Reverting to the question of analysis of aqua ammonia, it is believed that the quick detection of minute quantities of volatile substances which render aqua ammonia unfit for use in refrigerating machines will hardly be accomplished by chemical analysis. It is most likely that methods have to be resorted to which are based upon physical principles and which reveal actions of such impurities although they do not disclose their identity. In looking over the literature on the subject, I found a statement by G. Tammann in his investigation on vapor tensions (*Mémoires de l'Académie des sciences de St. Pétersburg* VII, série tome XXXV, No. 9, 1887, page 18) that apparently the increase of vapor tension of volatile substances following a decrease in space, which is occupied by the same vapors, is caused by minute impurities, and it would seem possible to use this observation for a method of testing volatile substances for purity. (Compare Ostwald, *Allg. Chemie*, I, pp. 306-309.)

This remark is prompted by the observation of A. Wullner and O. Grotrian (*Wiedemann Annalen*, XI, p. 600, 1880) that the vapor tension of volatile substances increases if the vapor volume is decreased.

Wullner and Grotrian found the increase of vapor tension for water smaller than for other volatile substances, yet it would be 5-10 mm. if the vapor volume was reduced from $\frac{1}{3}$ to $\frac{1}{10}$ of the original volume.

G. Tammann has repeated these experiments, and has found that there is no increase of vapor tension caused by decrease of vapor volume for water, *if it is pure*, and he succeeded in making water of sufficient purity to prove this fact.

For ether and carbon bisulphide he could materially reduce this irregularity by purifying the substances, but he could not make them sufficiently pure to show the same tension at varying volumes.

From this Ostwald (*Allgem. Chemie*, I, p. 309) draws the conclusion that no substance except water has ever been made of absolute purity.

G. Tammann then suggests that this observation might be used for a method of testing volatile substances for purity and

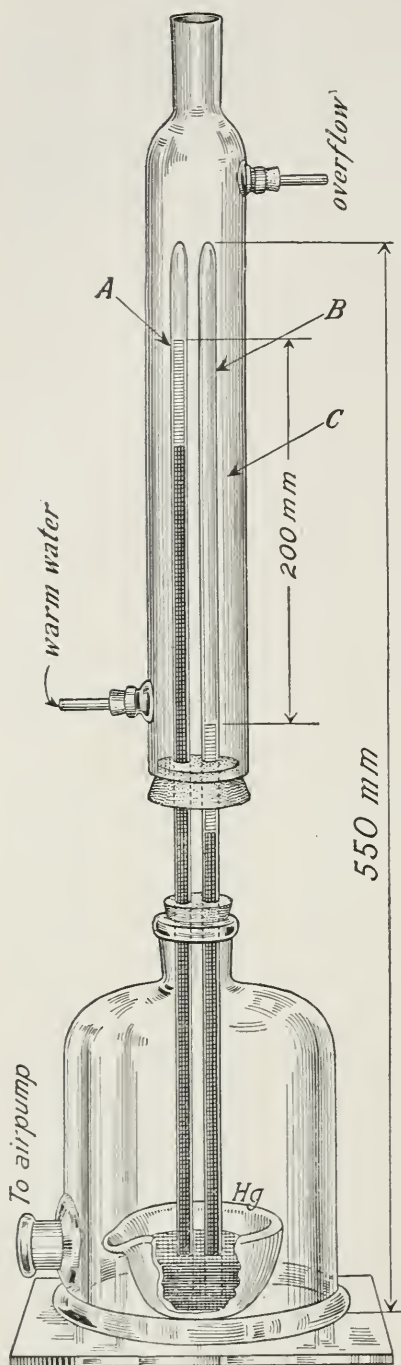


FIG. 7.

Ostwald states (I, 309) that one part benzene in 10,000 parts of water can be detected in this manner.

It has occurred to me that these observations may be used for determining volatile impurities in aqua ammonia in the following manner:

Two barometers are combined in one apparatus, the one of which is charged over mercury with a solution of pure sulfate of ammonia and pure water, the other with aqua ammonia, which is to be tested, and which previously was neutralized with pure sulfuric acid to make a solution of ammonium sulfate in water of the same concentration as the solution charged into the first barometer, and then the relative vapor tension in the two barometers at various temperatures is determined.

To prove the possibility of this method, apparatus shown in Fig. 7 was constructed having two barometers in a narrow space allowing of uniform heating of both barometers.

Two barometers were made from one length of glass tubing which was equally wide at both ends. The tube was drawn out to a point in the center and both points were closed. Therefore both barometers were equally wide near the closed end of the

tube and 1 cc. of mercury filled 22 mm. of the barometer tubes. For making the test both tubes were filled with mercury and the air was removed by repeated evacuation, and filling up with mercury. A 25 per cent solution of pure sulfate of ammonium in water was prepared from which air was expelled by boiling and methyl orange was added to prove acidity. 2.5 cc. = 2.825 g. of this solution were introduced into each barometer and in barometer *B* 0.015 g. benzene enclosed in a small flask was also inserted, whereupon the following readings were taken at various temperatures and various pressures.

Table IV shows that 0.003 per cent benzene can easily be detected in 25 per cent solution of sulfate by use of this apparatus.

TABLE IV

Temp. Deg. C.	Difference in Barometer, $B - A = \text{mm.}$	One mm. indicates Benzene %.
20	52	0.0106
27	77	0.0071
35	105	0.0051
45	148	0.0038
60	184	0.0030
70	200	0.0027
80	215	0.0026

I am well aware that the apparatus and experiments which I have presented to you are in no way exact and complete in the way physicists will look at them, and I would hesitate indeed to present them for publication in a physical journal. In no way can they compare with the investigations of H. C. Dickinson and N. S. Osborne, of the United States Bureau of Standards, on the constants of refrigeration. But incomplete as they are, they have served me as guides in the manufacture of pure ammonia for use in ice machines, and I find satisfaction in the assurance that the most painstaking investigations of McKelvy and Taylor have confirmed the fact that commercial liquid anhydrous ammonia of such purity is made that it is more worthy of the designation "chemically pure" than many other chemicals, which are sold at a high price as chemicals of highest purity.

Since writing this paper several months ago a singular case of unpreparedness has developed in the ammonia trade.

As you all know most ammonia is obtained as a by-product from gas works and from coke-oven plants. In gas works and in the older coke-oven plants the ammonia is obtained by scrubbing the gas with water and recovering the ammonia from the diluted gas liquor by distillation whereby free ammonia is obtained, which may be used in the manufacture of aqua and anhydrous ammonia and ammonium salts.

In the more modern coke-oven plants the so-called direct process is employed, in which only so much ammonia is obtained in the form of ammoniacal liquor as condenses with the water distilling from the carbonized coal. This amounts to only about 20 per cent of the total ammonia. The remaining 80 per cent are obtained by washing the gas with a slightly acid solution of sulfate of ammonia in small apparatus. These plants produce therefore a large amount of sulfate of ammonia, and they are not provided with scrubbers by the use of which all ammonia might be obtained as ammoniacal liquor. This was desirable in peace times because the larger part of ammonium salts was used in the fertilizer trade in the form of sulfate of ammonium.

But since the war demanded ever increasing quantities of nitrate of ammonium for explosives the necessary ammoniacal liquors were insufficient in quantity, and although much sulfate of ammonium was available, there was only one plant in the U. S. in which aqua ammonia could be made from sulfate and this plant was altogether engaged in the manufacture of ammonia for the refrigerating industry. And it had become necessary to reconstruct this one plant to adapt it to the use of crude ammoniacal liquor on account of the high price commanded by sulfate of ammonium during the war. Upon request of the Food Administration of the U. S. remodeling of the plant was temporarily abandoned and even a 50 per cent increase in capacity of the sulfate plant was agreed to for the purpose of securing ample supply for cold storage warehouses and ice plants, the Government aiding in obtaining a supply of sulfate of ammonium at reasonable cost.

After this was arranged there arose a sudden and large demand for ammonia for the manufacture of nitrate of ammonium, and sulfate of ammonium being the only available material it has to be manufactured from this ammonium salt.

There exists the singular condition that we have coking plants, which are prepared to make much sulfate, but which can make only

a limited amount of ammoniacal liquor, and we have nitrate ammonium plants which can work ammoniacal liquor but which cannot make nitrate of ammonium from sulfate. We have ample ammonia material but we are utterly unprepared to make nitrate of ammonium from it.

It is known that in England nitrate of ammonium is made by double decomposition of sulfate of ammonium and nitrate of sodium but it is understood that in this process about 20 per cent of the ammonia is wasted. To investigate this process a Commission went to England several weeks ago whose report by cable is expected now. But even in the case of a favorable report it is estimated to require 6 months before works of sufficient size can be put into operation.

Being one of the few chemists in the U. S. familiar with the manufacture of ammonia from sulfate, I was called to Washington to consult with officials of the War Department. Complete plans, patterns, assistance, and patent rights were promptly offered and accepted for the purpose of erecting new plants each the size of our St. Louis plant, about eight of which are contemplated for the various explosive works. This being actual conditions you have the singular opportunity to witness the unprecedented growth of an industry, which by economic conditions has outlived its usefulness, and which after the war must die out having become unprofitable under peace conditions.

Reconstruction of our St. Louis plant is being done under great difficulties and I must ask your indulgence if I show you this afternoon a sadly disarranged plant, which must be operated while it is being reconstructed. I had hoped to have the plant finished for this convention but demands of our Government changed the plans, and if I wish to keep my promise to you I must show the works as they are now.

The scarcity of ammonia is unprecedented and the importance of saving ammonia has become paramount. Waste of ammonia must be prevented at almost any cost, so much so that officials of the Government are intent to close ice plants where waste is permitted to continue.

For these reasons a report on the relation between efficiency of refrigerating plants and purity of their ammonia charge must be of greatest interest at this time since it tends to prove that pure ammonia and smallest waste of it are inseparable factors in the operation of refrigerating plants.

DISCUSSION

HUGH K. MOORE: I desire to ask Dr. Frerichs how hot he heated that oil. You had a test, Dr. Frerichs, to see whether it was suitable and you said it was heated, but you did not say how hot.

Dr. FRERICHS: The temperature is not a definite one. I heat from ten to ten degrees. The oil may be heated to two hundred, three hundred, or three hundred and fifty degrees, and any oil which at three hundred and fifty degrees would not give any gases, I would consider good. The apparatus is constructed to determine at what temperature the oil will develop gases, or whether it will develop gases at all. And I might say, that 80 per cent of all the oils which were tested did not give any gases at those temperatures.

DISTILLED WATER

By WILLIAM MILLER BOOTH

Read at the St. Louis Meeting, Dec. 5, 1917

HISTORICAL

THE Alembic is the earliest form of distilling apparatus with which we are acquainted. As shown in the cut (Fig. 1), this consisted of a boiling kettle, and a capital. Liquids were vaporized in the kettle and air condensed above. The quintessence of matter was supposed to be separated by such a process. Later the retort replaced the alembic and the vapor was transferred from the source of heat to a receiver. The latter was air or water cooled.

The purification and concentration of the vapors from many kinds of liquids required a broadening use of the distillation principle. Capacity and speed became necessary factors in the handling of large quantities of material. To make the condenser less unwieldy for large scale operations Baumé and his associates introduced the metal worm. For the laboratory, Liebig added a simplified tubular water-jacketed condenser which has become as standard a piece of apparatus as the Bunsen burner. The general impression prevails even to the present time that distillation is an almost absolute purifying process. All whose duties have required the accurate separation of volatile matters by distillation know that this popular idea is far from the truth.

For some time we have been interested in the purification of water for a variety of manufacturing processes. Following our effort to secure pure water we have examined the literature of the subject both in scientific journals and in the records of the United States Patent Office. The list of articles dealing with purification

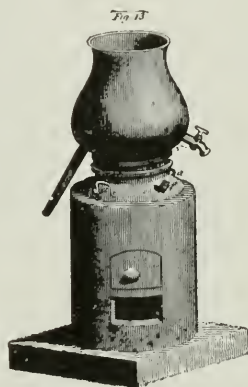


FIG. 1.—Alembic.

of water by distillation that has appeared in both chemical and engineering journals is appended to this paper, and shows that general interest in the *quality* of water used in manufacturing is of very recent date, and although the requirements of many industries and of all chemical laboratories demand the purification of water by distillation, the literature of the subject is very meager.

The purpose of this paper is to bring together some of the well-known facts connected with the purification of water—more particularly distillation and to show how the mineral and volatile constituents of ordinary water are separated during the distillation process—finally to discuss types of apparatus designed to produce exceptionally pure water for laboratory and commercial processes.

We have corresponded with a large number of manufacturers



FIG. 2.—Water Still.

during the past ten years in connection with their water problems, and have discovered a general attempt to purify water in large quantities at the lowest possible cost. Distillation is avoided if a satisfactory product can be obtained in any other way. In some instances the use of distilling apparatus has become compulsory. As early as the middle of the eighteenth century, patents were granted inventors on account of apparatus used to distil sea water aboard vessels of the English navy. Large distilling plants of high efficiency are operated in the arid localities of Africa and the Orient.

Because compelled to do so, the druggist distils water but uses a type of apparatus that was perfected one hundred and fifty years ago, Fig. 2, and we have known of instances where rain water, melted snow, or even soft spring water have been retailed from a drug store as a distilled product. When the druggist is prepared to furnish a

reasonably good grade of distilled water his retail price is usually excessive.

We have in mind the storage battery of the automobile which requires pure water but which is often damaged by the introduction of mineral salts from an impure sample of water sold by an ignorant or careless man. Fortunately the druggist is compelled to use pure water in compounding those prescriptions that include materials incompatible with mineral salts ordinarily found in the city or town supply.

Wherever the scientist has found it necessary to use an unusually pure water, he has had to invent a process and devise apparatus to meet his requirements. Our correspondence, which is made a part of this paper, shows this.

We divide the distilled water uses as follows:

1. Chemical and pharmaceutical.
2. Distilled water for ice and food purposes.
3. Drug stores and physicians.
4. Storage batteries.
5. College and technical laboratories.
6. Special research, physical-chemical investigation.
7. Bacteriological cultures and serums.

That we may understand the difficulties met in producing pure water it will be necessary to attack the subject from the chemical side. Nature takes highly mineralized, organically impure sea water which is the final wash from the land surface of the earth and by the simple process of vaporization produces a remarkably pure product. During the descent of rain through the air, gases are absorbed and dust particles are carried down. These remain in solution and suspension in precipitated water.

We have made analyses of rain water that fell into an open funnel during a heavy storm, Feb., 1910, and found the following, parts per million:

Total solids 100° C.	54.
Free ammonia.	.06
Albuminoid ammonia.	.094
Nitrogen in nitrates.	.00
Nitrogen in nitrites.	.30
Chlorine.	.00
Alkalinity.	1.25

An analysis of water caught upon a shingle roof and housed in a concrete cistern gave us the following results:

	Parts per Million.
Total solids.....	130.
Free ammonia.....	.30
Albuminoid ammonia.....	.15
Nitrates.....	.04
Chlorine.....	2.20
Nitrites.....	.06

Analysis of a sample of snow taken Feb. 4, 1910:

	Parts per Million.
Total solids *.....	24.
Loss on ignition.....	10.
Free ammonia.....	.02
Albuminoid ammonia.....	.025
Nitrogen in nitrates.....	.005
Nitrogen in nitrites.....	.006
Chlorine.....	Trace
Calcium.....	3.6
Magnesium oxide.....	.0
Alkalinity.....	8.

Second snow water analysis, November, 1910:

Total solids.....	54.00
Free ammonia.....	.06
Albuminoid ammonia.....	.094
Nitrates.....	.00
Chlorine.....	.00
Alkalinity.....	1.25

A large number of observers have proved that precipitated water is usually unreliable and an organically impure product.

After our rain and snow analyses were published, Dr. N. H. Miller of Rothamstead, England, kindly sent us a paper which gave analyses in detail relating to the snow and rain-water precipitation at that station for more than twenty years, from 1888 to 1909:

* These analyses were published in the December issue of the *Journal of Industrial and Engineering Chemistry*, 1910.

	Parts per Million.
Average nitrogen present as ammonia in the	
Rothamstead rain water.....	.447
Nitrogen pentoxide.....	.183
The chlorine for twenty-eight years averaged..	2.28
Sulphur trioxide from 1877 to 1888 averaged..	2.57

The same author includes analyses of rain water from many localities. In all instances ammonia and nitrates are present in quantities that make the water unfit for special purposes demanding a pure solvent.

It is generally conceded that freezing eliminates considerable of the mineral matter from water and our experience in connection with the analysis of ice bears out this idea.

Ice Analysis

	Parts per Million.	
	Lake Water.	Ice.
Total solids 100° C.....	156.	30.
Free ammonia.....	.031	.015
Albuminoid ammonia.....	0.09	.0075
Total.....	.121	.0225

A sample of ice taken from a pond in a hard water locality February 9, 1915, had the following analysis:

	Parts per Million.
Total solids 100° C.....	16.00
Chlorine.....	.00
Free ammonia.....	.053
Albuminoid ammonia.....	.10
Nitrogen in nitrates.....	.00
Nitrogen in nitrites.....	.003
Oxygen consumed.....	.37

Supplies from springs and surface waters contain organic matter, or mineral matter, or both.

The demands of modern industry require water that cannot be obtained from nature. By no process of heating, precipitation or filtration with which we are familiar, is it possible to totally remove the mineral matter from water. The remarkable Permutit process exchanges soda for lime and magnesium salts. Carbonates of calcium and magnesium, carbonic acid, and gypsum may be very much reduced in water heated to a temperature of 152° C. under pressure.

If we expect to get organically and minerally pure water we have to resort to distillation, and then only are we able to obtain this by especial treatment and apparatus.

It may be well at this point to outline the requirements set by scientific societies and the demands of manufacturers.

UNITED STATES DISPENSATORY

Seventeenth Edition, Pages 210-211.

“ Water one thousand volumes. To make eight hundred volumes. Distil the water from a suitable apparatus provided with a block tin or glass condenser. Collect the first one hundred volumes and throw this away. Then collect eight hundred volumes and keep the distilled water in glass stopper bottles, rinsed with hot distilled water immediately before being filled. Distil from a copper still connected with a block tin worm. No natural water is sufficiently pure for certain Pharmaceutical purposes; and hence the necessity of the above processes for its distillation. It is best to reject the first portion that comes over, as this may contain carbonic acid and other volatile impurities; and the last portion of the water ought not to be distilled, least it should pass over with an empyreumatic taste. The condenser is directed in the United States Pharmacopœia to be of block tin or glass. Distilled water as usually obtained has a vapid and disagreeable taste and is not perfectly pure, water to be rendered so requiring to be distilled in silver vessels. Distilled water should undergo no change by hydrogen sulphide or by the addition of tincture of soap, lead subacetate, barium chloride, ammonium oxalate, silver nitrate, or lime water. The transparency of distilled water should not be affected nor should any color be imparted to it by test solutions of hydrogen sulphide, or ammonium sulphide, or by those of barium chloride, silver nitrate, ammonium oxalate or mercuric chloride nor should its transparency be affected when mixed with

twice its volume of calcium nitrate test solution. It should give no reaction for nitrates or nitrites when tested as indicated under the subject "Water."

When 1000 c.c. of distilled water are evaporated on a water bath to dryness no residue should remain. On heating 100 c.c. of distilled water acidulated with 10 c.c. of diluted sulphuric acid to boiling and subsequently adding 1 c.c. of potassium permanganate centi-normal volumetric solution the color of the liquid should not be completely destroyed by boiling for ten minutes nor by afterwards setting the vessel aside well covered for ten hours."

Mr. Andrew Blair in his work entitled "Chemical Analysis of Iron," states that glass should not be used as a worm in a water distilling apparatus as notable quantities of the material are dissolved in the water.

De La Coux in "Industrial Uses of Water" states the following: Owing to the instability of salts of ammonium and magnesium chloride, water charged with these substances is liable to yield consequent on their decomposition a distillate impregnated with ammonium and lye, hydrochloric acid.

As a first precaution the operation should not be carried out to a finality, and the amount of distillate collected should only be equal to three-fourths of the original volume of water; in other words the last portion of the water in the retort should be thrown away.

Another method is to add to the water in the retort, before applying heat, some substance that will have the effect of reducing the instability of these various objectionable compounds. Thus in the case of water charged with ammonia, the ammonia is fixed by the addition, before distillation of magnesium phosphate, while, in the case of water containing carbonic acid, milk of lime is substituted.

Frequently laboratory distilled water is found to be acid owing to the hydrochloric acid produced by the decomposition of magnesium chloride. In this case it is well to render the water slightly alkaline by the addition of sodium or potassium, so as to obtain double chlorides of magnesium and of the metal of the alkali, which are far more stable than the simple chlorides.

Organic matter is liable to be carried over in distillation. It will therefore be advisable to clean the retort thoroughly before commencing work, especially if the preceding operation empyreumatic substances have been distilled.

If the water contains organic matter, distillation should cease

when three-fourths of the amount has been evaporated. Also potassium permanganate may be added in the retort.

By closely following these instructions distilled water is obtained that will be found suitable for all ordinary purposes; but should water of an extreme degree of pureness be required for some special purpose, the operation must be carried out as follows:

A strongly acid solution of potassium permanganate must be added to the water and the distillate must be redistilled with an admixture of aluminium sulphate.

As a result of this treatment the distillate will be free from all trace of ammonia, of chloride and of organic matter. More often than not the distilled water used in manufacture has not been specially prepared but consists of the water obtained by condensing the steam from the boilers that serve to drive machinery.

This water, which is equally a product of distillation, is liable to the same objection arising from mechanical agency which we have had occasion to notice in connection with distilled water properly so called; that is to say, hydrochloric acid and ammonia are just as often found in it.

It is important to bear in mind that preparations intended to counteract calcareous deposits are frequently introduced into steam boilers.

These preparations, which are often bought of the manufacturer without any information as to their composition, occasion decomposition of one form or another, and the resultant matter is carried into the condensed vapor, so much so indeed that the distilled water is rendered unfit for manufacturing purposes.

Fatty matters are also frequently carried over. These arise from grease or oil accidentally dropped into the boiler or driven into it from about the lubricated parts of the engine, such as the cylinder, the slide-valve chest, and so forth. Vegetable and animal grease and oils, characterized by saponifiable fatty acids, are particularly detrimental to water obtained by condensation. This kind of water therefore should be carefully tested before use.

Any fatty or saponifiable matter may, however, be eliminated by fixing its fatty acid with milk of lime.

WATER DISTILLED*

 H_2O . Mol. Wt. 18.02

Distilled water must be neutral to litmus paper

Test of Purity

Ammonia and Ammonium Compounds. 50 c.c. of the water should show no change on the addition of 10 to 15 drops of Nessler's reagent. (Indicating less than 0.00002 per cent NH_3 .)

Chlorides. 100 c.c. of water should show no change on adding a few drops of nitric acid followed by silver nitrate solution. (Indicating less than 0.00001 per cent Cl.)

Sulphates. On adding 1 c.c. of hydrochloric acid and some barium chloride solution to 100 c.c. of water, no precipitate of barium sulphate should form on standing fifteen hours. (Indicating less than 0.0002 per cent SO_3 .)

Nitrates. Introduce 5 c.c. of diphenylamine solution (see Diphenylamine) into a test-tube, and overlay it with 10 c.c. of water. No blue color should form at the contact-surfaces of the two liquids. (Indicating less than 0.0007 per cent N_2O_5 .)

Non-volatile Matter. 100 c.c. of the water evaporated on the water-bath should leave no weighable residue. (Indicating less than 0.0005 per cent.)

Heavy Metals and Calcium. 100 c.c. of the water show no change with hydrogen sulphide water (indicating no heavy metals present) or ammonia water with ammonium sulphide, or ammonium oxalate solution. (Indicating less than 0.0002 per cent Ca.)

Substances Oxidizable by Permanganate (Organic Matter, Nitrites, etc.). Heat to boiling 100 c.c. of the water with 1 c.c. of 16 per cent of sulphuric acid, add 1 drop of potassium permanganate solution (1 : 100), and maintain the boiling for three minutes. The liquid should not be decolorized. (Indicating none present.)

Our experience with the distilled water furnished the college laboratories in which we have worked has shown this to have been generally of inferior quality and quite incapable of meeting the requirements set by careful scientific men, unless re-distilled. The total solids and organic matter found in the supply of one university were respectively 25 and 10 parts per million, due to the presence of a

* Chemical Reagents, Their Purity and Tests, E. Merck & Co., Second Edition, page 180, 1914.

large amount of ammonia and oil. Nitrites have often been found present. With impure distilled water it is impossible to do accurate scientific work. Solutions of salts of silver and of permanganate of potash require the best water obtainable. It is impossible to read burettes accurately when the solutions to be measured contain even a trace of oil.

While we have high standards of purity, little is to be found in the literature of the subject regarding the changes that take place in a given sample of water during heating, boiling or distillation. To show the progress of purification we have made tests with our local city supply as a basis.

By standard methods of analysis we have found the following:

Parts per Million.		
As received.....	.....	Distilled
Sediment.....	None	
Appearance.....	Transparent	
Total solids 100° C.....	130	2.
Residue after ignition.....	90	1.
Chlorine.....	1.94	Volumetric chlorine blank .30 mg. per 100 c.c. Silver ni- trate, no precipita'n.
Free ammonia.....	.005	.005
Albuminoid ammonia.....	.049	.000
Nitrogen in nitrates.....	.36	.00
Nitrogen in nitrites.....	.000	.000 sometimes trace
Free carbon dioxide.....	2.94	.63
Half-bound carbon dioxide...	42.00	
Sulphur trioxide.....	8.00	.00
Calcium oxide.....	43.75	.00
Magnesium oxide.....	8.28	.00
Silica.....	.40	.00
Iron.....	.31	.00
Dissolved oxygen and nitrogen, temp. 8.5° C.*	36.30 c.c.	
Percentage dissolved oxygen..	32.34	
Alkalinity.....	94.	Varies with kind of apparatus used.

* Gases measured at 15.5° C.

AIR IN WATER AND ITS MEASUREMENT

All natural waters contain from $1\frac{1}{2}$ to 3 per cent of air by volume depending principally upon the temperature. This air begins to separate from the water considerably below the boiling-point, and is the cause of the geyser, like action that takes place just prior to the actual separation of water vapor. Many processes require the separation of this air before use. Its quantity may readily be measured with the following simple apparatus: a wide-mouth Erlenmeyer flask of about a liter capacity is provided with a close-fitting solid rubber cork. A piece of glass tubing about 3 feet in length and 8 mm. in internal diameter is drawn to a tapering point, about $\frac{1}{2}$ inch of the taper is cut off and the edge is burnished with a flame. The opposite end is also burnished and made slightly conical with a file. The tapered tip is fitted with a piece of heavy-walled rubber tubing about $2\frac{1}{2}$ inches long, and a clamp is applied at the center just beyond the tip of the tube. A second piece of glass tubing about 5 feet long and 8 mm. in internal diameter is drawn nearly to a point at one end. By means of a cork borer moistened with caustic soda solution the rubber cork is perforated by three holes in a form of a triangle. Two of these holes are of sufficient size to fit the tubes already prepared. The third carries a thermometer. The first tube is pushed upward through the cork until the cone at the lower end is flush with the cork itself on the under side. The conical end of the second tube is pushed within about an inch of the bottom of the flask. The thermometer is put in place and the apparatus is weighed. The flask is filled with water, and the stopper is wired to the flask. The clamp is released from the upper end of first tube and air pressure is exerted at the upper end of the second tube until the first is entirely filled with water. The clamp is now closed. The water level should not rise above the cork of the second tube. The apparatus is again weighed. This gives us the weight of water used. By means of a 2-inch piece of rubber tubing fit the mouth end of a 50 c.c. pipette to the upper end of the second tube, place the apparatus on a wire gauze, support vertically, and heat gently until air ceases to rise in the first tube. Temperatures may be taken during this process as a matter of interest. The gases that have been separated from the water in this way are transferred to a regular gas apparatus. Some carbon dioxide will be set free. This and the oxygen are absorbed in pipettes

and measured. Our results are shown under the table "Syracuse Water."

SEPARATION OF HALF BOUND CARBON DIOXIDE

One liter of raw water was distilled into lime water, 50 c.c. at a time. The precipitated lime salt was filtered, washed, and the lime estimated. The results are as follows:

1st 50 c.c.....	8.60 mgs. CO ₂
2d "	7.90 "
3d "	6.80 "
4th "	5.50 "
5th "	4.55 "
6th "	1.10 "
7th "	.20 "
	34.65 mgs. CO ₂

Second test with baryta water:

1st 50 c.c.....	8.25 mgs. CO ₂
2d "	7.32 "
3d "	6.02 "
4th "	5.45 "
5th "	4.61 "
6th "	2.79 "
7th "	2.07 "
8th "	1.40 "
	37.91

This water contains 42 mgs. CO₂ per liter.

The carbon dioxide is therefore pretty well separated when one-third of the water is evaporated.

To determine the alkalinity of successive fractions distilled from raw water we titrated 100 c.c. distillates. One-half liter of raw water was added to a 2-liter boiling flask with glass stopper, and neck bulged at the outlet tube immediately beneath the stopper. The Bunsen burner consumed 10 cubic feet of gas per hour. The free surface of the water was 28 cm. below the outlet. A glass tube 8 mm. in internal diameter was fitted to the delivery tube of the flask. Their total length was 160 cms. A 35-cm. condenser jacket was

fitted over this tube and 100 c.c. lots of water were distilled and tested for alkalinity using methyl orange as the indicator. The results follows:

1st 100 c.c.....	1.08 c.c. N/50 H ₂ SO ₄
2d "	.48 "
3d "	.36 "

The process was repeated:

1st 100 c.c.....	1.11 c.c. N/50 H ₂ SO ₄
2d "	.48 "
3d "	.39 "

82.5 cm. were now cut from the glass condensing tube and the process was repeated in duplicate:

1st 100 c.c.....	.31 c.c. N/50 H ₂ SO ₄
2d "	.29 "
3d "	.29 "
1st 100 c.c.....	.39 "
2d "	.29 "
3d "	.27 "

One liter of water was now distilled using the same short tube apparatus with the following results:

1st 100 c.c.....	.52 c.c. N/50 H ₂ SO ₄
2d "	.52 "
3d "	.38 "
4th "	.48 "
5th "	.48 "
6th "	.48 "
7th "	.45 "
8th "	.33 "
9th "	.38 "
10th "	.40 "

One-half liter of water was placed in a boiling flask and distilled through the condenser jacket previously used and carrying a block thin tube of length and external diameter identical with that of glass tube 82.5 cms. long.

The alkalinity of the distillates was found to be:

1st 100 c.c.....	.65 c.c. N/50 H ₂ SO ₄
2d "	.60 "
3d "	.30 "
4th "	.37 "
5th "	.37 "

A tin-lined copper dish was now substituted for the glass flask, the tin condenser remained the same, the burner the same. One-half liter was used as before.

Distillates had the following alkalinity:

1st 100 c.c.....	.44 c.c. N/50 H ₂ SO ₄
2d "	.38 "
3d "	.30 "
4th "	.25 "

Acidity with methyl orange; fiftieth normal soda solution; 1 liter raw water was distilled:

	CO ₂ Parts per Million.
1st 100 c.c.....	.45
2d "	.19
3d "	.25
4th "	.14
5th "	.27
6th "	.22
7th "	.19
8th "	.17
9th "	.19
10th "	.13
	2.20

One liter of Syracuse water was treated with .100 g. freshly burned calcium oxide, was shaken and allowed to stand four hours. Fractional distillates were titrated with N/50 NaOH solution—methyl orange was used as an indicator.

Syracuse water distilled from glass.

		Carbon Dioxide Found per Million.
1st 100 c.c.	.....	.170
2d "	.....	.113
3d "	.....	.121
4th "	.....	.113
5th "	.....	.113
		.630

One gram of pure calcium chloride was added to 250 c.c. of distilled water in a glass boiling flask and three 100 c.c. lots were distilled and tested for chlorine. None was found. One gram of rusted iron wire was added and the distillation was continued until two 100 c.c. lots had come over. No chlorine was found in either of these distillates.

One gram of C. P. magnesium oxide was neutralized with hydrochloric acid. The slight excess of acid was evaporated at 100° C. and the resulting salt was placed in a boiling flask with 250 c.c. of distilled water.

The distillates contained the following chlorine:

1st 20 c.c.	.....	.54 mg.
2d "	.....	.34 "
3d "	.....	.44 "
4th "	.....	.49 "
5th "	.....	.49 "
6th "	.....	.84 "
7th "	.....	1.29 "

The progressive increase of chlorine in the distillates is pronounced.

Wanklyn in "Water Analysis" tenth edition, page 41, states that the first 50 c.c. of distillate from a 500-c.c. sample of water invariably contains three-fourths of the free ammonia present; that is, 10 per cent of the distillate contains 75 per cent of the ammonia. Our own results showing analyses of water that contain varying amounts of free ammonia are as follows:

Parts per Million.

1st dist.	4.30	13th dist.	.86	24th dist.	.16
2d	3.44	14th	.86	25th	.16
3d	.86	15th	.645	26th	.14
4th	.86	16th	.43	27th	.14
5th	.86	17th	.43	28th	.06
6th	.86	18th	.215	29th	.03
7th	.86	19th	.215	30th	.02
8th	.86	20th	.215	31st	.02
9th	.86	21st	.17	32d	.02
10th	.86	22d	.17	33d	.00
11th	.86	23d	.167	34th	.00
12th	.86				
Total NH ₃ found,				21.467 mgs.	

One liter of ammonia-free water was treated as above and the distillates were titrated with N/50 H₂SO₄.

Alk. Reckoned as NH₃.

1st distillate	100 c.c.	34.38 c.c. = 11.69 mgs.
2d	" "	12.80 " = 4.35 "
3d	" "	5.34 " = 1.81 "
4th	" "	1.95 " = .65 "
5th	" "	1.40 " = .47 "

NITRITES

We distilled successive portions of 50 c.c. each from 1 liter of raw water and tested these distillates for *nitrites*. The results follow:

Parts per Million.

1st 50 c.c.	.....	.003
2d	"	.000
3d	"	.000

We now added a solution containing .20 mg. of nitrogen as nitrite. The distillation was continued with pronounced nitrite reaction. .100 g. potassium permanganate was now added and complete absence of nitrite in the distillate was shown. The water was acid in reaction. .100 g. of caustic soda was added and the distillate tested for nitrous acid and acidity. No nitrous acid was found and the distilled water had an alkaline reaction.

Cooling water used per liter of water distilled, minimum.

Condenser:

Glass.....	15 liters
Block tin, same size and length.....	10
Copper tinned within, used as a constant level apparatus.....	6

The tubes in each instance were 8 mm. in internal diameter, and 80 cm. long. A 35 cm. glass condenser jacket was used in all of these experiments.

Water distilled in one hour with a 10-cubic foot capacity Bunsen burner producing 580 B.T.U. per hour.

Glass flask.....	600 c.c.
Copper dish.....	1320 "
Constant level copper boiling kettle using hot water from condenser.....	1800 "

INTERMITTENT APPARATUS

The ordinary drug store still is usually made from copper; consists of a boiling kettle, goose neck, and a condenser. The latter may be straight or curved. The whole of the apparatus is block-tin lined. The boiling kettle may be set upon the stove or may be heated by gas, gasoline, kerosene, or electricity. The still is charged to capacity at one time and the first 10 per cent of distillate is discarded as well as, the last 10 per cent. If such an apparatus has a capacity of from 5 to 10 gallons, it may prove useful and economical, but it is usually manufactured in 1 or 2 gallon sizes which make its handling and use, time consuming and cumbersome. Thousands of druggists own and occasionally operate such apparatus.

Manufacturers who require from 5 to 500 gallons of distilled water of a fair degree of purity duplicate the above using a boiling kettle and block-tin worm condenser. As the top or cover is usually bolted to the body of the still it is very difficult to open the latter and it therefore occurs that the interior is seldom clean. One of the most important features of distillation is the removal of organic matter. If this is allowed to accumulate in the boiler it becomes a serious source of contamination with an ordinary water supply. If a considerable quantity of water is to be distilled with any degree of frequency we consider an intermittent apparatus time consuming.

CONTINUOUS APPARATUS

Mr. A. M. Coyle in patent No. 364,199 granted in May, 1887 claims that an automatic feed to a distilling apparatus is a new feature. The same principle is used in the constant level water-bath, and is as simple as it is efficient. A part of the condensing water, usually

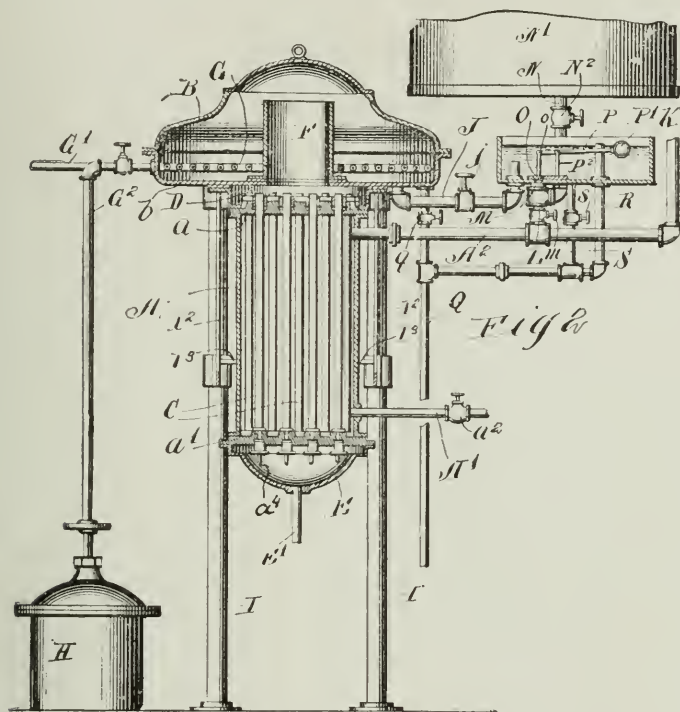


FIG. 3.—Jewell Distilling Apparatus.

from one-fourth to one-sixth passes from the condenser into the boiling kettle, and the remainder is allowed to run to waste over a small weir fixed at the same horizontal level as that of the liquid within the boiler. It is easily seen that no considerable pressure can be carried in the boiler as the water will pass out of this side orifice. In actual practice a continuous distilling apparatus with a condenser too small in diameter, or run beyond its capacity will force the water from the kettle until equilibrium is established, then the water will again enter, the process being repeated continuously. Hoffman,

Ahlers & Company, who manufacture large distilling apparatus units, use a float valve within the boiling kettle and maintain the liquid at a uniform level. This makes it possible to connect the inlet with a high-pressure feed-water line. Patent No. 552,688 was issued to I. H. Jewell, Jan., 1896, for the production of a compact constant-level water-distilling apparatus in which the condenser was placed

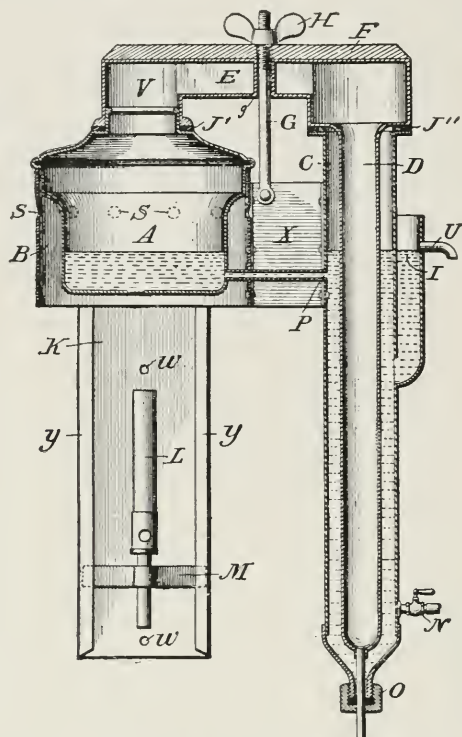


FIG. 4.—Rochlitz Water Distilling Apparatus.

at the axis of and below an ample boiling kettle, the interior of which was easily reached through a hand hole above. The apparatus was gas-driven by a ring system of Bunsen burners. By this invention Mr. Jewell simplified the process of distillation for gas and steam. There are now many forms of apparatus on the market that are adaptations of Mr. Jewell's invention.

Patent No. 885,943, July, 1897, was taken out by A. G. Waterhouse. He claims the following: "My improvement in the art

of distilling therefore further consists in mechanically reducing the pressure upon the liquid to be vaporized and mechanically increasing the pressure upon the vapor to be condensed, and transferring the entire heat of condensation to the liquid to be vaporized." This

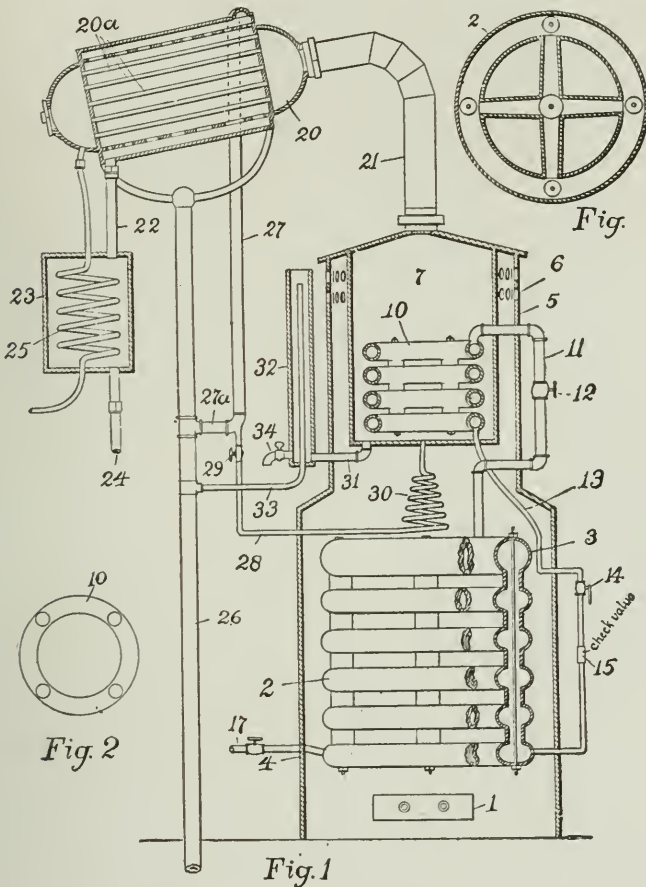


FIG. 5.—Barnstead Water Still.

apparatus undertakes to evaporate under reduced pressure using this heat through mechanical compression. This is a very interesting patent as an attempt is made to utilize the latent heat of steam in a practical way. Waterhouse was granted patent No. 643,702 for an elaboration of his process. Jewell improved his constant level

apparatus in patent No. 692,788. In this he uses a steam coil multiple condenser tube and a float valve. Patent No. 713,298 was awarded to W. F. M. Goss, Nov., 1902. "For a process of distillation and

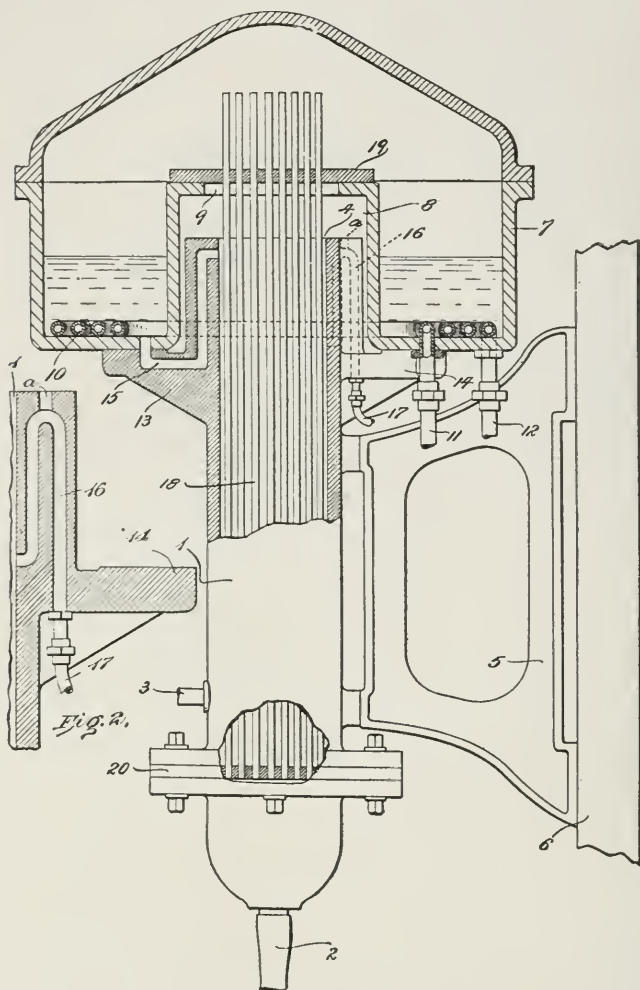


FIG. 6.—Stokes Water Still.

evaporation in multiple effect, that is, the evaporation of a portion of a liquid, condensing the vapor so produced by another portion of the vapor, employing the condensate for evaporating still another

portion thereof, inducing a flow of the liquid toward the portion first adapted, and inducing the flow of the condensate in the opposite direction." In this apparatus we have the elements of the

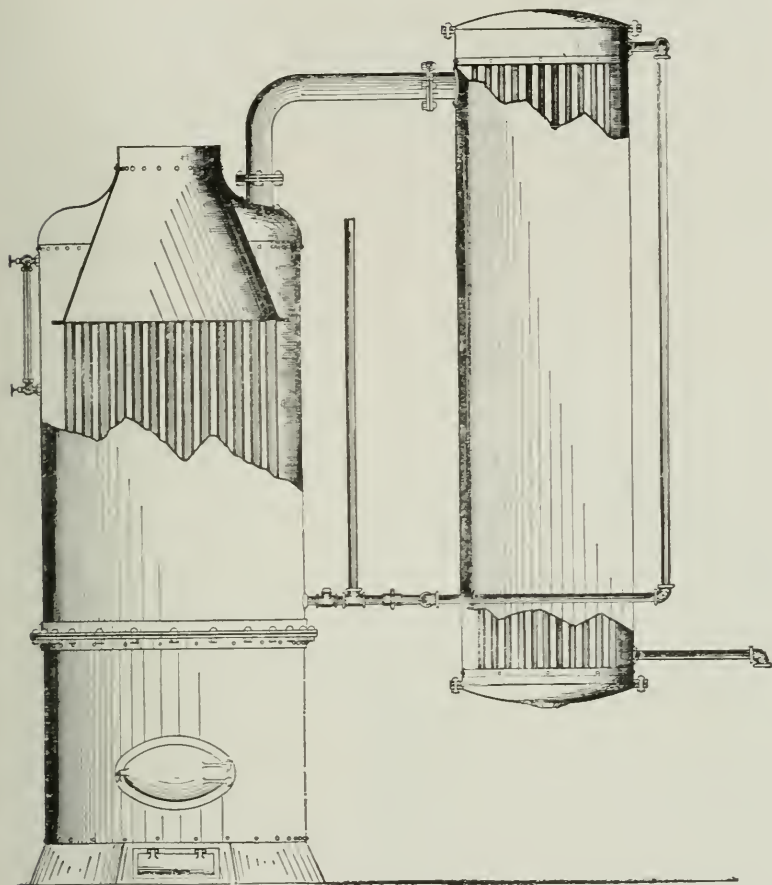


FIG. 7.—Hoffman-Ahlers Coal-driven Still. Capacity, 20 gallons per hour.

high efficiency multiple evaporator. Patent No. 682,631 issued in 1907 to W. F. M. Goss shows a multiple vacuum apparatus, complex and of high efficiency.

COST OF DISTILLING WATER

Steam

The efficiency of the ordinary horizontal return tubular boiler is about 60 per cent, that is, we may expect to distil a gallon of water

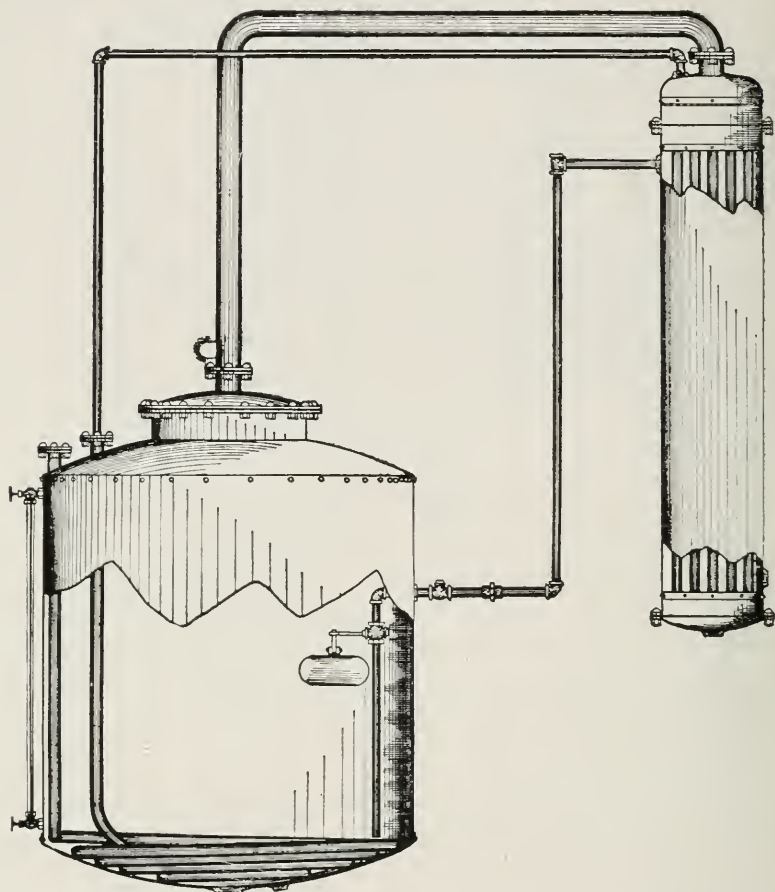


FIG. 8.—Hoffman-Ahlers Steam-driven Still. Capacity, 20 gallons per hour.

with 1 pound of steam coal of the average grade, and containing about 13,500 B.T.U. per pound. To this must be added the cost of water used in cooling the distillate unless this water can be used again in other parts of the plant. If the condenser is run economically

from 4 to 6 gallons of water will be required for every gallon of distilled water produced. If the cost of water is low this item is not large, but the use of city water for condensing purposes alone in connection with distilling apparatus and run at atmospheric pressure is a considerable item. It is safe to say that a gallon of water produced under these conditions will cost about one-fifth of a cent. The thermal efficiency of any atmospheric pressure apparatus can be increased about 20 per cent by heating the incoming water by the condensing steam.

A multiple effect distilling plant of large capacity can be operated at a very low cost for distilled water. Ernest-Scott & Co. of Fall

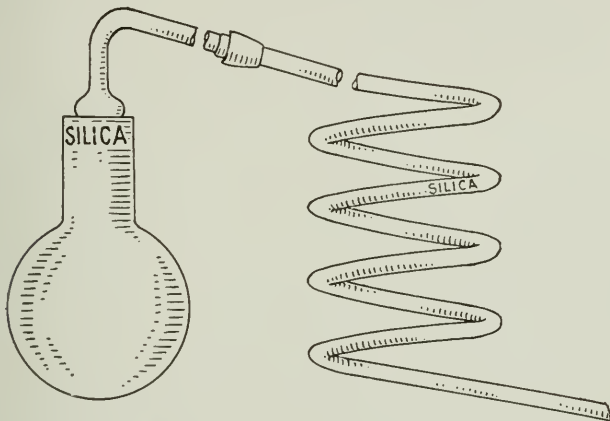


FIG. 9.—Quartz Water Still. (Courtesy of Leads and Northrup Co.)

River, Mass., guarantees 70 pounds of pure distilled water per pound of coal. This is at the rate of about \$2.50 per thousand gallons. Distilling plants of exceptionally high efficiency have been operated at a fuel cost of \$1.50 per thousand gallons.

Apparatus of a capacity of from 10 to 100 gallons per hour of distilled water heated by coal or similar fuel naturally falls within the class of the steam boiler, and the expense would not be much greater. Where steam is used through a coil in an evaporating plant the expense is slightly in excess of the above.

Gas with ring or Bunsen burners is quite generally used in apparatus of a capacity from a few quarts to 2 or 3 gallons per hour. Whether the apparatus is intermittent or continuous the incoming water is usually heated, and the efficiency remains between 60 and

80 per cent. If gas is purchased at \$1.00 per thousand cubic feet, and carries about 600 B.T.U. per cubic foot, the water produced costs about $2\frac{1}{2}$ cents per gallon. We have used kerosene as a source of heat and have found that the cost is about the same as gas, that is that 1 pound was required to distil a gallon of water. An electric hot plate is very expensive as a source of heat. We produced 1

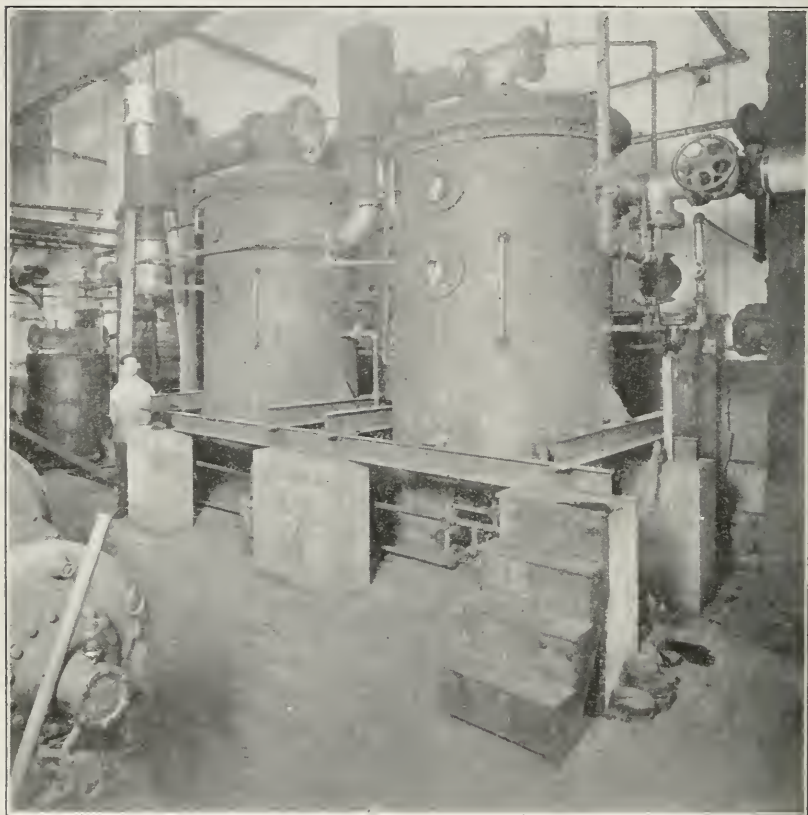


FIG. 10.—Two 54"×72" Evaporators and Auxiliaries for Distilled Water.

gallon of water at a cost of \$1.04. Between two o'clock in the morning and six o'clock electric experts consider the actual value of a kilowatt hour of electricity a very small fraction of one cent. At this time electricity can be employed as a source of heat in a distilled water plant to good advantage, and the cost would not preclude its use.

An ordinary Bunsen burner consuming about 10 cubic feet of gas per hour and heating a glass distilling apparatus, will produce about .75 liter of water per hour and requires at least 12 liters of cooling water. These figures are given from the use of a Liebig glass condenser. From the standpoint both of time and water consumed, distillation from glass is a relatively expensive operation.

Cost of Apparatus (Approximate)

Apparatus; Steam. Steam Boiler Types. Copper-tin lined, 20 gallons per hour, coil and copper condenser. \$300-\$450.

Coal-driven Stills. Iron fire box set in brick, copper boiler, tubular iron condenser, copper tubes all tin lined:

10 gallons per hour.....	\$250
20 gallons per hour.....	\$350
1000 gallons per day.....	\$1250

OPERATION

The supply pipes for a distilling apparatus must be coupled with great care. No oil or oil-bearing materials should be used at the joints. If the pipe fitters are careless in this particular several days may be required to produce a satisfactory water. If the water supply contain oil it should be treated hot with caustic lime or caustic soda and filtered. A reliable man with mechanical knowledge should be placed in charge of a water still of any considerable capacity and the details of successful operation should be carefully explained. The boiling kettle should be cleaned at fixed periods, mud and sludge blown or washed out and scale removed by scraping, sandpaper or muriatic acid. The water in the boiling kettle should be regulated by a constant-level feed. Rapid boiling of the water should be avoided. Economical use of cooling water is necessary. The distilled product should be protected from acid fumes, air and dust. We recommend closed containers lined with porcelain.

TESTING

Water prepared for scientific purposes or for particular manufacturing operations should be tested often for carbon dioxide, alkalinity, total solids and total solids on ignition. Conductivity tests may be used to good advantage. These tests are recommended in addition to those prescribed by the Pharmacopœia or Merck.

SUMMARY

Natural waters must be distilled to make them sufficiently pure for use by manufacturers who require a mineral free water, also for scientific work. Water used by pharmacists and physicians should be prepared with great care.

We cannot expect to obtain a pure product from a source containing organic pollution.

The usual impurities in distilled water are:

(a) *Mineral Matter.* This may be carried over with the steam because the distance between the level of the boiling water and the outlet is not great enough and the difficulty may be entirely eliminated by raising the outlet.

(b) *Oil.* Boiler waters that include returns often carry oil. Some natural waters contain enough dissolved organic matter to produce an oily distillate when decomposed by heat. The use of a separator in the steam line removes the larger part of this. We prefer to use steam in an evaporator supplied with oil-free water.

(c) *Ammonia.* Free ammonia is distilled from waters carrying organic matter. If alkalies are used in the still, or if a very high temperature is employed nitrogenous matter will be broken down with an addition ammonia yield. Ammonia-free water may be obtained by acidifying the supply with sulphuric or phosphoric acid. An improved distillate may be produced by boiling the water in an open vessel previous to distillation. The most of the free ammonia may be separated by boiling off 35 per cent of the volume of the water. We have removed 98 per cent of the total ammonia in water by filtration through charcoal.

(d) *Carbon Dioxide.* Although Syracuse city water carries about 40 mgs. of half-bound carbon dioxide and about 2 mgs. of free carbon dioxide per liter we found a very small percentage of this compound in the distilled water. However, distilled water may rapidly absorb CO_2 from the air. Consequently all containers should be closed except when in use. Carbon dioxide may be fixed by the use of caustic soda, caustic lime or barium hydroxide. Heating to the boiling-point in an open container will remove a considerable quantity.

(e) *Fixed Alkalies.* Condensation should be carried on in block-tin-lined or silver tubes. Glass should not be used.

(f) *Nitrites*. Nitrites may be oxidized by the use of potassium permanganate in acid or alkaline solution.

(g) *Chlorine*. Caustic soda should be used in sufficient quantity to form common salt with the calcium and magnesium chlorides present. If chlorides are entrained the level of the steam outlet should be raised.

(h) *Copper*. No copper surface should be exposed in a condensing system.

(i) What has been said above in reference to copper also applies to iron.

(j) From the engineering or operating standpoint we suggest the following: The production of distilled water in any considerable quantity requires a careful preliminary study with complete analyses of raw water and distillate. The plant installed should be placed in charge of an intelligent attendant who should run the apparatus without forcing, should flush the boiling kettle daily, and wash this thoroughly at stated periods.

A good combination of the parts of a steam distilling apparatus of a capacity of from 10 to 500 gallons of water per hour is a magnesia or felt-covered cylindrical heating kettle or evaporator provided with a conical bottom and ample sludge valve. The steam coil should remain submerged in the water during the operation of the still and should be removable for cleaning purposes. The copper coils ordinarily found in vacuum pans are well placed and easily cleaned. A water glass and steam gauge should be provided. The height of the outlet above the water level will be fixed by the size and shape of the boiling kettle. We suggest that it should not be less than 18 inches in a kettle 36 inches high. The top should be clamped by easily opened swivel bolts, an upright cylindrical column tin-lined and carrying tinned baffle plates should be placed between the top of the still vertically and the tubes leading to the condenser. The latter should be coupled to the body of the still by an easily opened union without bolts. This applies also to the opposite end of the goose neck. No rubber or organic matter should be used in the gaskets. Asbestos or soft metal may be used. The condenser should be of non-corrosive metal lined with block tin, and should be so constructed as to be taken down and cleaned. We prefer to deliver the distilled water to the containers at nearly the boiling temperature. Dust particles or air should be excluded as far as possible.

In the selection of a raw water supply for distillation, we recommend:

- (1) The use of a soft water low in organic matter—for instance, clean rain water or the city or town supply.
- (2) The use of a moderately hard but pure water.
- (3) The use of a hard but organically pure water softened by the soda-lime or Permutit process.

In any instance we recommend the previous treatment of a natural water in a long baffled shallow container carrying a steam coil by which the water on its way to the evaporator may be boiled violently with the release of air and CO_2 , and vaporization of at least 10 per cent of its volume, the steam thus produced being used to heat the incoming water. Check tests should be run upon the distilled water frequently and the blanks so obtained used in all analytical computations. Young chemists accepting commercial positions should insist upon an ample, constant and pure distilled water supply. This is one of the primary requisites of accurate work. For miscellaneous public use we suggest the production and sale of "certified" distilled water labeled and sealed in clear glass-stoppered bottles made from special insoluble glass.

To the universities, corporations and individuals that have taken part in our questionnaire we extend our hearty thanks.

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Frank T. King, Brooklyn, N. Y. Apparatus for distilling. No. 328,316; Oct. 13, 1885.

Abram G. W. Rankin, Jersey City, N. J. Domestic water-distilling apparatus. No. 346,221; July 27, 1886.

Lionel Harvey Pearce, Coalbourne, Stourbridge, County of Worcester, England. Means for vaporizing and distilling liquids. No. 348,772; Sept. 7, 1886.

- Robert Davis Gladney, Klownville, Miss. Apparatus for distilling water and other liquids. No. 378,881; Mar. 6, 1888.
- Pascal B. Charboneau, Bay City, Mich. Apparatus for distilling water, No. 383,704; May 29, 1888.
- Andrew J. Chase, Boston, Mass. Apparatus for distilling water. No. 392,498; Nov. 6, 1888.
- Philip Henry Bracher, Wincanton, County of Somerset, England. Distilling Apparatus. No. 403,638; May 21, 1889.
- Frederic H. Moore, Boston, Mass. Apparatus for purifying water. No. 411,292; Sept. 17, 1889.
- Andrew J. Sweeney, Wheeling, W. Va. Distilling apparatus. No. 415,227; Nov. 19, 1889.
- Nelson Hunting, Albany, N. Y. Apparatus for distilling water. No. 448,041; Mar. 10, 1891.
- John McGarvey, Allegheny, Pa. Condenser. No. 460,398; Sept. 29, 1891.
- Nelson Hunting, Albany, N. Y. Distilling apparatus. No. 468,913; Feb. 16, 1892.
- Johannes Peterson and Louis Liebeck, New York, N. Y. Water-still. No. 478,458; July 5, 1892.
- Mathias J. Reuber and Edwin G. Stone, Pittsburg, and Peter Fuchs, of Lower St. Clair, Pa. Condensing apparatus. No. 488,664; Dec. 27, 1892.
- James E. Thomas and Elisha P. Grow, Bay City, Mich. Water-distilling apparatus. No. 491,028; Jan. 31, 1893.
- John F. Chase, Augusta, Maine. Vaporizer. No. 492,979; Mar. 7, 1893.
- Edwin Ruud, Pittsburg, Pa. Automatic distilling apparatus. No. 496,488; May 2, 1893.
- Winslow Allderdice, Warren, Ohio. Apparatus for distilling water. No. 497,742; May 16, 1893.
- James E. Thomas and Elisha P. Grow, Bay City, Mich. Aerating Distilled Water. No. 502,408; Aug. 1, 1893.
- James E. Thomas and Elisha P. Grow, Bay City, Mich. Apparatus for aerating distilled water. No. 502,409; Aug. 1, 1893.
- William Rochlitz, Chicago, Ill. Water-distilling apparatus. No. 505,641; Sept. 26, 1893.
- Charles H. Denison, Springfield, Mass., Distilling Apparatus, No. 511,730; Dec. 26, 1893.
- Frank Edward Wallace, East Orange, N. J. Distilling apparatus. No. 515,413; Feb. 27, 1894.
- Josef Nagel, Chemnitz, Germany. Apparatus for obtaining distilled and sterilized water. No. 523,230; July 17, 1894.
- Thomas Craney, Bay City, Mich. Process of purifying water. No. 524,887 Aug. 21, 1894.
- Andrew J. Chase, Boston, Mass. Apparatus for distilling water. No. 530,015; Nov. 27, 1894.
- Edward Lynah Jackson and William Fitzgerald, Memphis, Tenn. Water still. No. 532,377; Jan. 8, 1895.
- Josef Nagel, Chemnitz, Germany. Apparatus for distilling and sterilizing water. No. 532,390; Jan. 8, 1895.
- John H. Vinton, Boston, Mass. Apparatus for distillation and aeration of water. No. 534,412; Feb. 19, 1895.
- Edward C. Hargrave, Bay City, Mich. Water-distilling apparatus. No. 552,835; Jan. 7, 1896.

Wallace G. Minor, Los Angeles, Cal. Water-still and water-heating and cooking appliance. No. 556,157. Mar. 10, 1896.

Jeffrey O. Bentley, Philadelphia, Pa. Still. No. 557,102; Mar. 31, 1896.

Confucius Chase and Andrew J. Chase, Boston, Mass. Apparatus for distilling water. No. 558,775; April 21, 1896.

Martin L. Sargent, Wichita, Kansas. Apparatus for distilling water. No. 562,326; June 16, 1896.

James McCabe, Bay City, Mich. Apparatus for procuring pure water. No. 565,686; Aug. 11, 1896.

Louise L. Painter, Sag Harbor, N. Y. Combined tea-kettle and still. No. 577,267; Feb. 16, 1897.

Alexander McVeigh Miller, Alderson, W. Va. Still attachment for stoves or ranges. No. 585,686; July 6, 1897.

Frank Rosebrook, Chicago, Ill. Distilling and Aerating Apparatus. No. 587,162; July 27, 1897.

William O. Pierce and Benjamin F. Bigelow, Gridley, Cal. Water-distilling apparatus. No. 587,506; Aug. 3, 1897.

Joseph Stretch, East Orange, N. J. Apparatus for distilling water. No. 604,550; May 24, 1898.

John Ezra Hicka, Columbus, Ohio. Domestic water distiller. No. 611,123; Sept. 20, 1898.

John Stocker, St. Louis, Mo. Distilling apparatus. No. 614,776; Nov. 22, 1898.

Jared A. Todd and Harry G. Smith, Titusville, Pa. Fluid-distilling apparatus. No. 616,277; Dec. 20, 1898.

John D. C. Brown, Chicago, Ill. Distilling Apparatus. No. 623,880; April 25, 1899.

John F. Chase, St. Petersburg, Florida. Water-still and condenser. No. 627,904; June 27, 1899.

Clarence M. Kemp, Baltimore, Md. Apparatus for distilling and aerating water. No. 633,851; Sept. 26, 1899.

James White Hale, Newburyport, Mass. Water-still. No. 634,556; Oct. 10, 1899.

Charles S. Kinney, Arroyo Grande, Cal. Water-heater condenser. No. 641,597; Jan. 16, 1900.

Joseph E. Cross, Brattleboro, Vermont. Distilling apparatus. No. 641,437; Jan. 16, 1900.

Charles F. Conover, New York, N. Y. Apparatus for producing distilled water. No. 645,790; Mar. 20, 1900.

Jason S. Bentz, Columbus, Ohio. Combined water still and heater. No. 648,337; Apr. 24, 1900.

Arthur R. Bailey, New York, N. Y. Water-still. No. 650,501; May 29, 1900.

Daniel W. Hawkes, Portland, Maine. Water-still. No. 665,738; Jan. 8, 1901.

Dickinson L. Rose, Mankato, Minnesota. Water-distilling apparatus. No. 669,966; Mar. 12, 1901.

Washington Irving Avery, New York, N. Y. Water-still and condenser, No. 676,172; June 11, 1901.

Guy W. Davis, Portland, Me. Water-still. No. 678,230; July 9, 1901.

John Spratt Wrightnour, Oil City, Pa. Apparatus for rendering pure and palatable water. No. 681,289; Aug. 27, 1901.

Albert Powers, St. Louis, Mo. Still. No. 687,262; Nov. 26, 1901.

Andrew J. Chase, Boston, Mass. Apparatus for distilling water. No. 697,912; April 15, 1902.

Emma Jester, Pueblo, Col. Distilling apparatus. No. 698,958; Apr. 29, 1902.

Edward E. Murphy, Boston, Mass. Apparatus for distilling water. No. 698,724; April 29, 1902.

Edward Warren and George W. Healy, Fort Thomas, Arizona Territory. Still. No. 714,339; Nov. 25, 1902.

John Kirkaldy, London, England. Portable distilling apparatus. No. 718,209; Jan. 13, 1903.

John Ellison, Spanish Fork, Utah. Apparatus for distilling water. No. 718,991; Jan. 27, 1903.

John F. Chase, St. Petersburg, Florida. Water-distilling apparatus. No. 720,671; Feb. 17, 1903.

James T. Van Ausdal, Independence, Kansas. Combined washboiler and water-distilling apparatus. No. 625,182; April 14, 1903.

Thatcher P. Wilson, Easthaven, Conn. Water-still. No. 734,486; July 21, 1903.

Albert Le Cocq De Lautreppe, New York, N. Y. Still. No. 744,367; Nov. 17, 1903.

John Stocker, St. Louis, Mo. Distilling apparatus No. 748,564; Dec. 29, 1903.

George A. Young and Charles A. Young, Detroit, Mich. No. 759,747; Jan. 26, 1904.

Frederick H. Smith, Chicago, Ill. Water-still. No. 755,179; Mar. 22, 1904.

John S. Forbes, Philadelphia, Pa. Apparatus for evaporating or distilling. No. 760,440; May 24, 1904.

Lewis E. Beers, Aspen, Col. Distilling apparatus. No. 782,377; Feb. 14, 1905.

Ethan B. Keith, Galesburg, Mich. Water-still. No. 790,901; May 30, 1905.

Ernest E. Morlan, Kansas City, Kansas. Distilling apparatus. No. 793,732; July 4, 1905.

Gottlieb Knodler, New York, N. Y. Apparatus for producing purified water. No. 792,426; June 13, 1905.

Louis E. Beers, Aspen, Col. Distilling apparatus. No. 797,255; Aug. 15, 1905.

Dennis William Daley, Parkersburg, W. Va. Water-distilling apparatus. No. 797,843; Aug. 22, 1905.

Robert P. Barnstead, Boston, Mass. Domestic water-still. No. 806,450; Dec. 5, 1905.

George Franklin Wentz, St. Louis, Mo. Distilling apparatus. No. 815,392; Mar. 20, 1906.

Charles Rufus Dudley, Sykesville, Md. Apparatus for distilling water. No. 824,630; June 26, 1906.

Robert P. Barnstead, Boston, Mass. Domestic water-still. No. 825,178; July 3, 1906;

Orin Parker, Dubuque, Iowa. Apparatus for distilling water. No. 829,999; Sept. 4, 1906.

George Franklin Wentz, St. Louis, Mo. Distilling apparatus. No. 833,271; Oct. 16, 1906.

Ernest A. Le Sueur, Sault Ste. Marie, Ontario, Canada. Process of distillation. No. 838,195; Dec. 11, 1906.

Oscar Alfred Nenninger, El Paso, Texas. Water-still. No. 842,687; Jan. 29, 1907.

Nicolas Broonoippolito, Allegheny, Pa. Filter and distiller. No. 845,929; Mar. 5, 1907.

Dennis William Daley, Charles Alexander Gunn, and Frank Richard Daley, of Pittsburg, Pa. Combined water heater and still. No. 849,210; April 2, 1907.

John F. Chase, St. Petersburg, Florida. Water-purifying apparatus. No. 851,160; April 23, 1907.

John A. Power, New York, N. Y. Multiple-condenser water-still. No. 878,744; Feb. 11, 1908.

Arthur R. Bailey, New York, N. Y. Water-still. No. 882,811; Mar. 24, 1908.

Joseph R. Perry, Wilkes-Barre, Pa. Device for distilling water. No. 901,645; Oct. 20, 1908.

Dennis William Daley, Pittsburg, Pa. Combined hot-water heater and still. No. 902,277; Oct. 27, 1908.

Arthur William Blunden, Sebastopol, Col. Kettle-still. No. 911,467; Feb. 2, 1909.

Horace P. Snyder, Grand Rapids, Mich. Apparatus for distilling water. No. 916,798; Mar. 30, 1909.

George S. Edelen, Washington, D. C. Means for automatically regulating, the supply of heating medium for scientific and similar apparatus. No. 923,957; June 8, 1909.

Henry J. Behrens, Winona, Minnesota. Water-still. No. 932,950; Aug. 31, 1909.

Oscar A. Nenninger, El Paso, Texas. Distilling Device. No. 952,343; Mar. 15, 1910.

Henry C. Duensing, Chicago Heights, Ill., Distilling Apparatus. No. 1,043,305; Nov. 5, 1912.

Dennis William Daley and Frank Richard Daley of Parkersburg, W. Va. Hot-water system. No. 1,061,359; May 13, 1913.

Martin L. Dunnam, Meridian, Miss. Combined condenser and feed-water heater. No. 1,076,410; Oct. 21, 1913.

Berthold Bleicken, Gross-Borstel, Near Hamburg, Germany. Apparatus for producing distilled water. No. 1,102,131; June 30, 1914.

Dennis William Daley, Parkersburg, W. Va. Still and water-heater. No. 1,116,804; Nov. 10, 1914.

Joseph A. Manahan, New York, N. Y. Water-still. No. 1,145,497; July 6, 1915.

Thomas P. Adams, Chicago, Ill. Water-still. No. 1,148,273; July 27, 1915.

Calvin D. Crane, Dayton, Ohio. Water-still. No. 1,154,590; Sept. 21, 1915.

Weeden B. Underwood, Erie, Pa. Process of obtaining sterilized and distilled water. No. 1,183,142; May 16, 1916.

Eugene N. Baldwin, Joliet, Ill. Condensing attachment for tea-kettles. No. 1,199,147; Sept. 26, 1916.

Clifford G. Jack, Garrison, Nebraska. Steam-condenser. No. 1,210,322; Dec. 26, 1916.

George W. Crispell, Albany, N. Y. Still. No. 1,231,857; July 3, 1917.

Valdemar G. Mellgreen, Tombstone, Arizona. Water-distiller. No. 1,237,079; Aug. 14, 1917.

DISTILLING APPARATUS OF AN ENGINEERING TYPE

A. Normandy, France. Improvement in distillation of fresh water from salt water. No. 21,693; Oct. 5, 1858.

G. W. Baird, Engineer Corps, United States Navy. Improved apparatus for ærating and cooling distilled water. No. 93,852; Aug. 17, 1869.

Terry Almy, Williamson, N. Y. Improvement in water-heaters and purifiers. No. 122,346; Jan. 2, 1872.

William Hale Herrick, Grinnell, Iowa. Apparatus for distilling water and other fluids. No. 284,011. Aug. 28, 1883.

Franz Littmann, Halle-a-Saale, Germany. Improvement in apparatus for preparing water for ice-machines. No. 214,161; April 8, 1879.

August Gerdes and Burchard Thoens, New Orleans, La. Process of distilling water. No. 425,316; Apr. 8, 1890.

Frederic H. Moore, Boston, Mass. Apparatus for purifying water. No. 424,124; Mar. 25, 1890.

Edward A. Quisenberry. Manufacture of ice. No. 460,029, 460,030; Sept. 22, 1891.

George W. Baird, Washington, D. C. Steam generator or evaporator. No. 450,361; April 14, 1891.

Thomas Craney, Bay City, Mich. Apparatus for purifying water. No. 515,819; Mar. 6, 1894.

Horace H. Hodges and David J. Havenstrite, Boston, Mass. Method of and apparatus for distilling water. No. 520,525; May 29, 1894.

Louis Block, New York, N. Y. Apparatus for preparing water for the manufacture of ice. No. 529,356; Nov. 20, 1894.

Addison G. Waterhouse, Hartford, Conn. Process of an apparatus for distilling liquids. No. 585,943; July 6, 1897.

Addison G. Waterhouse, Philadelphia, Pa. Method of distilling and evaporating water. No. 643,702; Feb. 20, 1900.

William F. M. Goss, Lafayette, Ind., Distilling Apparatus. No. 713,297; Nov. 11, 1902.

William F. M. Goss, Lafayette, Ind. Process of distilling liquids. No. 713,298; Nov. 11, 1902.

Jesse Monroe Coffman, Montalvo, Cal. Water-distilling apparatus. No. 732,831; July 7, 1903.

Horace F. Hodges and Joseph Kuen, Philadelphia, Pa. Method of Purifying water. No. 798,964; Sept. 5, 1905.

Horace Franklin Hodges, Philadelphia, Pa. Apparatus for purifying water. No. 798,901; Sept. 5, 1905.

Horace F. Hodges and Joseph Kuen, Philadelphia, Pa. Water-still. No. 799,002; Sept. 5, 1905.

Horace F. Hodges and Joseph Kuen, Philadelphia, Pa. Apparatus for purifying water by distillation. No. 799,003; Sept. 5, 1905.

Robert P. Barnstead, Boston, Mass. Water-still. No. 823,488; June 12, 1906.

Walter H. Bartholomew, East Orange, N. J. Distilling apparatus. No. 829,756; Aug. 28, 1906.

Robert T. Gunn, Norfolk, Va. Process-making potable and aerated water. No. 835,866; Nov. 13, 1906.

Jacob F. Wittemann, Brooklyn, N. Y. Apparatus for distilling. No. 845,285. Feb. 26, 1907.

Jacob F. Wittemann, Brooklyn, N. Y. Method of distilling. No. 845,286; Feb. 26, 1907.

John E. Siebel, Chicago, Ill. Art of distilling, concentrating and evaporating liquids. No. 849,579; Apr. 9, 1907.

William F. M. Goss, La Fayette, Ind. Distilling Apparatus. No. 862,631; Aug. 6, 1907.

Walter H. Bartholomew, East Orange, N. J. Distilling apparatus. No. 879,236; Feb. 18, 1908.

William F. M. Goss, La Fayette, Ind. Apparatus for treating liquids. No. 890,227; June 9, 1908.

Henry E. Deckebach, Cincinnati, Ohio. Liquid purifier and separator. No. 921,811; May 18, 1909.

Nicolai H. Hiller, Carbondale, Pa. Method of evaporation and apparatus therefor. No. 955,965; Apr. 26, 1910.

Albert Baudry, Kief, Russia. Process of purifying and sterilizing water. No. 958,848; May 24, 1910.

John Hoffhine, N. F. Harriman, Omaha, Neb. Still. No. 969,625; Sept. 6, 1910.

Nicolai H. Hiller, Carbondale, Pa. Method of evaporation and apparatus therefor. No. 970,051; Sept. 13, 1910.

William H. McCune, Vandergrift, Pa. Self-cleaning still. No. 1,010,508; Dec. 5, 1911.

Nicolai H. Hiller, Carbondale, Pa. Evaporating apparatus. No. 1,024,576; Apr. 30, 1912.

Burchard Thoens and Sumner S. Shears, New York, N. Y. Multiple still. No. 1,069,829; Aug. 12, 1913.

Nicolai H. Hiller, Carbondale, Pa. Method of Evaporation and apparatus therefor. No. 1,071,740; Sept. 2, 1913.

Emanuel Nobel and Serguis Bessenoff, St. Petersburg, Russia. Apparatus for regenerating the latent heat of evaporation of liquids. No. 1,118,041; Nov. 24, 1914.

Joseph A. Manahan, New York. Water still. No. 1,145,497; July 6, 1915.

Adolf P. Link, Brooklyn, N. Y. Water still. No. 1,150,439; Aug. 17, 1915.

David Pelton Moore, Washington, D. C. Triple purification still. No. 1,204,300; Nov. 7, 1916.

Carl Theodor Throssell, Gottenborg, Sweden. Method of evaporation and distillation of liquids. No. 1,204,716; Nov. 14, 1916.

John S. Forbes, Philadelphia, Pa. Method of and apparatus for distilling and evaporating. No. 1,232,269; July 3, 1917.

Frank Taylor Evans, United States Navy. Method of obtaining pure water from salt water. No. 1,225,118; May 8, 1917.

DISTILLING APPARATUS, CONSTANT LEVEL STILLS

Andrew M. Coyle, Washington, D. C. Method of and apparatus for distilling water. No. 364,199; May 31, 1887.

Robert P. Barnsted, Boston, Mass. Apparatus for distilling water. No. 456,922; July 28, 1891.

William Rochlitz, Chicago, Ill. Apparatus for distilling water. No. 743,164; April 19, 1892.

Theodore G. Springer, Chicago, Ill. Apparatus for distilling water. No. 550,849; Dec. 3, 1895.

Ira H. Jewell, Chicago, Ill. Distilling apparatus. No. 552,688; Jan. 7, 1896.

- Henry A. Steber, Utica, N. Y. Distilling apparatus. No. 576,910; Feb. 9, 1897.
- Henry A. Steber, Utica, N. Y. Distilling apparatus. No. 640,970; Jan. 9, 1900.
- Ira H. Jewell, Chicago, Ill. Distilling apparatus. No. 692,788; Feb. 4, 1902.
- William Rochlitz, Chicago, Ill. Water distilling apparatus. No. 771,832; Oct. 11, 1904.
- Henry A. Steber, Utica, N. Y. Distilling apparatus. No. 780,536; Jan. 24, 1905.
- John Hammond Smith, Allegheny, Pa. Still. No. 814,405; Mar. 6, 1906.
- Lambert Kleitz, Chicago, Ill. Distilling apparatus. No. 818,831; April 24, 1906.
- Jacob Henry Ullrick, Nashville, Tenn. Still. No. 851,045; April 23, 1907.
- Francis J. Stokes, Philadelphia, Pa. Still. No. 861,485; July 30, 1907.
- Milton B. Blouke, Chicago, Ill. Distilling apparatus. No. 919,685; Apr. 27, 1909.
- John A. Power, Babylon, N. Y. Triple-purification water-still. No. 988,661; Apr. 4, 1911.
- Ira H. Jewell, Chicago, Ill. Still. No. 999,793; Aug. 8, 1911.
- James De Sett Bennehoff, Alfred, N. Y. Water-distilling apparatus. No. 1,011,016; Dec. 5, 1911.
- John Marion Harsh, Cleveland, Ohio. Water-distilling apparatus. No. 1,013,936; Jan. 9, 1912.
- Russell H. McMillen, Wheeling, W. Va. Still. No. 1,019,069; Mar. 5, 1912.

CORRESPONDENCE IN CONNECTION WITH PAPER UPON "DISTILLED WATER"

ALPHA PORTLAND CEMENT COMPANY

Easton, Pa.

I can simply state that we use the Jewell still and test distilled water for chlorides only. What little potash or lime the water contains makes no difference to us.

L. Anderson, Jr.,
Chemical Engineer.

J. T. BAKER CHEMICAL CO.

Phillipsburg, N. J.

Yours of the 5th received. We use large quantities of distilled water, about 1500 gallons a day, and make it in the indirect method, passing steam into water previously heated in the condenser system. We use tin-lined vessels entirely and obtain a very pure water. We have no analysis of the distilled water in particular nor have we an analysis of the raw water. We are sorry that we

cannot give you any more interesting information, but this is all we have to offer.

J. T. Baker, Pres.

CLARK UNIVERSITY

Worcester, Mass.

We have recently perfected in this laboratory a still which gives practically pure water. I should say that for ordinary purposes the best means for specifying the purity of pure water would be to state the specific conductance. Ordinary distilled water has a specific conductance of about as low as 2×10^{-6} and a very good quality of the distilled water has a specific conductance as low as 1.0×10^{-6} .

It is not feasible to handle water of specific conductance below 1.0×10^{-6} for the reason that it would absorb carbon dioxide from the air. I have been able to obtain water with the specific conductance below $.05 \times 10^{-6}$, but I hardly think that this would be of particular interest in ordinary work. I may state, however, that water of this purity can be obtained with ease by a single distillation from ordinary distilled water and in any quantity. For the purpose of purifying water, I would recommend the distillation from alkaline permanganate solution, discarding, perhaps, as much as the first half of the water.

Charles A. Kraus, Director.

Woodbridge, N. J.

It is not surprising that there should be lack of uniformity in prevailing methods for producing distilled water for manufacturing purposes, for the reason that requirements vary so widely.

Where the object is merely to avoid incrustation or scale, as in some types of absorption towers, almost any condensate will do, such, for example, as the discharge from drips and heating coils. Such water, of course, always contains more or less iron.

By using a steam-coil of brass, copper, tin or aluminum, you can obtain a distillate substantially free from iron, provided the steam-line is drained so that the steam entering the coil is dry.

Where a very pure water is wanted in not too large quantities, I have found it satisfactory to condense high-pressure steam direct from the boiler, using fittings exclusively of aluminum or block tin; for mechanical reasons the valve must be of bronze.

If the feed to the boiler is drawn from an artesian well, and it is passed through an open heater before being pumped to the boiler, the distillate will be substantially free from volatile organic compounds and dissolved gases.

Colby Dill.

GENERAL ELECTRIC COMPANY

Research Laboratory

Schenectady, N. Y.

We produce distilled water for four distinct purposes:

The oxy-hydrogen electrolytic plant requires a large quantity. For this work we use an iron drum about 18 inches in diameter and 30 inches high, containing an iron steam-coil and a float valve. The condenser is an iron coil and no precaution is exercised to prevent spray being carried over. About a half pound of sodium hydrate is placed in the tank every week, and the steam and water valves opened. At the end of the week a draw-off valve is opened and the tank thoroughly flushed out. This still produces about 50 gallons per day.

For the storage-battery work we have a small lead coil arranged to condense plant-steam. We do not get enough oil to do any harm.

For tungsten purification and general use, we have a still which was made at the Massachusetts Institute of Technology. It consists of a copper drum, tin-lined, which contains a tin-covered copper steam-coil and a tinned ball float cock. The water furnished this drum is taken from the hot-water mains, thereby getting a soft water to start with. Steam goes to the heater coil at about 15 pounds pressure.

On top of this drum there is a vertical cylinder about 5 inches in diameter and 12 inches long, which contains ten baffle plates. This drum is also tin-lined, and from the cylinder a tin condenser pipe is connected. Storage is kept in large porcelain vats. The water obtained from this still is of fairly high quality, but we have been unable to maintain the standard necessary for the analytical laboratory.

For analytical work we are using a modified Jewell still. An extra valve is added so that the reservoir may be flushed thoroughly at frequent intervals. The still is used at about one-half capacity.

Glass and rubber are omitted entirely, and the water is stored in tin-lined copper tanks.

These are all quite common methods of producing distilled water, and please note that our plan is to let harmless impurities go through where large quantities of water are needed. We do not get perfection and we expect to make some changes after your paper is published.

Robert Palmer.

EDWARD GUDEMAN, Ph.D.

Chicago, Ill.

I have no special specifications as to distilled water. I very seldom am in the market to buy any. I have found years ago that I could not buy a satisfactory water for analytical purposes. My own specifications for myself are freedom from ammonia compounds and free from mineral matter.

It is surprising how little attention is paid to the purity of distilled water. I have seen in many laboratories, even of official bodies, where the distillate from an automatic still, fed by the city water, is used for all purposes. I have seen errors as high as 2 per cent protein ($N \times 6.25$) due to the ammonia contents of the water used in making the determination.

My own method of making distilled water for general laboratory purposes consists in using an automatic still which has an attachment to feed in some alkali (either calcium or barium hydrate). The distillate is redistilled from a similar still, automatically fed the first distillate, and the second distillation is made after making the distillate distinctly acid with phosphoric acid.

I generally make from 10 to 15 gallons for a run, and after 3 to 4 gallons have distilled over, cut out the next 5 gallons, the middle run, and use this for special purposes.

I have no analyses of the distilled water I use, except that it is free from ammonia salts, chlorine, residues and carbonic acid. Test for above impurities being made on 500 c.c. samples.

When possible I distil with steam, otherwise use gas. For commercial purposes, distilled water for drinking purposes, I recommend double distillation with vacuum pans, and automatically charge the first pan with slack lime and the second with sulphuric acid or phosphoric acid.

Edward Gudeman.

HALCOMB STEEL CO.

Syracuse, N. Y.

Replying to your inquiry of October 3rd concerning preparation of distilled water, advise that we produce our distilled water here in a home-made still, which is a cylinder about 24 inches diameter by 36 inches high, top of which for the entire cross-section is removable, to admit of thorough cleaning, which we find to be necessary each day. This still is heated by a spiral steam-coil and is operated so as to produce about 5 gallons of distilled water every hour. The depth of water is maintained at about 10 inches and should never be less than 8 inches, nor more than 12 inches.

The scale-forming carbonates and sulphates are precipitated with caustic soda by putting the caustic into the still in the morning after it is cleaned and filled ready for starting. All distilled water before it is used is tested with barium hydroxide, using about 20 c.c. of the saturated solution for 60 c.c. of water in a 10×1-inch test tube. The water to be acceptable for our use must be of such purity that no cloudiness appears or precipitate settles in it on standing an hour. (If there is to be any precipitate at all, it may be detected very quickly by comparison of the water containing the test with the one containing water only.)

Water that is used for gravimetric sulphur determinations is also treated with barium chloride, but we find that an appreciable amount of sulphate is not infrequently left behind, even after treatment with caustic soda.

Blank determinations are always made on water and other reagents for all analyses.

In the past where distilling for laboratory use, water carrying organic matter, I have in some cases made it a daily practice to introduce potassium permanganate into the still. I have never found this practice necessary with Skaneateles water.

One general observation I make on distilling water for analytical purposes is that the water-level is allowed to go up too high and in too close proximity to the distillate outlet. Disregard of this allows extraneous matter to be carried along mechanically with the distilled water to a far greater extent than apparently is generally thought to be the case.

George M. Berry,
Chief Chemist.

THE HARTFORD LABORATORY CO.

Hartford, Conn.

It has not been our custom to make regular definite tests of our distilled water, as we have never run into any difficulty which could be assigned to impurities in the water used. We have expected some difficulty from the use of chlorine as a disinfectant in the Hartford city water, but have never noticed any trouble from this source, and inasmuch as we use silver nitrate daily, without any evidence of chlorides in the water, we feel pretty sure that our water is all right in that respect.

As we have given up the sanitary analysis of water, owing to the small demand among our clients, we have not had to prepare nitrite- and ammonia-free water, and so we have not had difficulty in this respect.

C. L. W. Pettee.

JOHNSON & JOHNSON

New Brunswick, N. J.

In our laboratory proper we use an Electric Barnstead Still, both for chemical work and for use in the hundreds of storage batteries that are used in the works, particularly for the little motor trucks that carry cases and packages around through the yards and buildings of the plant. This produces, we believe, exceedingly pure water and once in a while we evaporate some to dryness and weigh the residue to keep track of how it is working. We do not, however, carry this out regularly and have kept no records.

A. W. Clark.

LAFAYETTE COLLEGE

Easton, Pa.

I can add very little of interest to your discussion on distilled water, since I have never made a careful study of the subject. I have gone far enough, however, to know that a sufficient supply for ordinary purposes for the laboratory can be made in a cast-iron vessel over a coal fire used primarily as a muffle furnace. In my private laboratory the apparatus, of my own design, made in this way is being used constantly, and has given entire satisfaction. I can not very well, without a diagram, show how I am able to

keep the rust entirely out of the distilled water, but the device is a very simple one and will occur to any one designing such an apparatus.

The advantage of using cast iron is that the material is practically inert toward the acids which occur in the air of the laboratory and in the gases from the muffle. Furthermore, if the fire is not urged too vigorously, the apparatus may be allowed to run dry without serious harm resulting. This cast-iron vessel is connected by means of a pipe made of block tin or tinned copper with a condenser also made of tinned copper, care being taken that the steam and water come only in contact with the tin.

My water supply in this particular case has been collected from a roof, and kept in a cement cistern. No particular care has been taken to exclude roof washings from the cistern, which is periodically cleaned. I have used this distilled water for some time now, and found it entirely satisfactory, but as I said I have made no particular study of the subject. Perhaps it will interest you to know that the furnace which I use for this purpose has a fire pot $12 \times 12 \times 12$ inches. Over the fire is the muffle, and above the muffle a cast-iron pot. The amount of coal used for this fire is very small indeed. The furnace is built with a fire-brick lining, so far as is necessary, and the rest of it is made of reinforced concrete. I find this very satisfactory.

All the necessary joints are closed with fine asbestos mixed with a little silicate of soda.

I think a real study of distilled water such as you propose would be extremely interesting. I have always told my students that since each water has a fauna and flora of its own, the distillate must in each case be different, just as the distillate from water containing a mouse would differ from the distillate of water containing cabbage, so that many distillation products must be expected, some of which might be harmful.

Edward Hart.

RICHARD K. MEADE

Baltimore, Md.

In our laboratory we are not very particular as to the quality of this beyond assuring ourselves that it is free from lime, magnesia, and sulphates. We very seldom make an ammonia determination and when we do we usually distil water especially for this pur-

pose. The city water which we use is soft water, quite free from mineral matter, but high in organic impurities. We find that our distilled water gives such a slight residue of mineral matter as not to affect our analyses in any way and it is also free from sulphates. As our analyses are principally of engineering materials, metallurgical products, etc., this answers our purpose. Our checks usually show from 2 to 3 milligrams per liter of mineral matter. Some of this, however, may be dissolved from the glass containers into which the water is distilled. We find the impurities in our ammonia and other reagents affect our results much more than does distilled water.

Richard K. Meade.

Brooklyn, N. Y.

We have a small still with a tin-lined condenser, using city water as our supply and steam heat for distillation. We find small traces of chlorine in our distilled water, but not enough to interfere with our chemical work. We have no analyses of our distilled water, and the raw water is the regular New York City supply.

Philadelphia, Pa.

The large bulk of our distilled water is made in a steam-heated still with tin condenser; two small laboratories use gas heated stills of Jewell type. The analysis of water going to stills is as follows:

Turbidity	0.0
Total solids.....	83.0
Total organic nitrogen	.19
Nitrites	.00006
Nitrates.....	.40
Oxygen consumed	1.9
Hardness.....	47.3
Alkalinity	28.6
Chlorine	4.8
Iron	.14
Dissolved oxygen.....	9.9

The distilled water is free from organic matter and is sufficiently pure for our purpose, but we regret not being able to give you a complete analysis or more information.

ERNEST SCOTT & COMPANY

Fall River, Mass.

We have no analyses of raw and distilled water, but may say that some time ago for one of the large incandescent gas mantle companies we completed a contract for a water distilling plant using muddy river water in which there was also a considerable quantity of chemical waste.

Our guarantee concerning purity of distilled water was that it should not contain more than .01 per cent of solid impurities. This guarantee was easily fulfilled. This apparatus was a quadruple effect working with pressure steam and no part of it was under vacuum. On actual test we furnished 4 pounds of distilled water per pound of steam at 60 pounds pressure used by the plant. In other words, this quadruple effect gave the theoretical efficiency of 4 to 1.

Of course the amount of distilled water per pound of steam used depends upon the number of effects and we have furnished considerably more distilled water than 4 pounds per pound of steam in cases where a larger number of effects than a quadruple effect was used.

In our water-distilling plants when we state that we use a quadruple effect, we mean that there are four effects, the first of which provides steam for the second, the second provides steam for the third and the third for the fourth. We mention this because some makers of water-distilling plants, when providing a multiple effect, not only use initial steam in the first effect, but also at other points in the effects to rejuvenate the steam. To our mind this is a travesty of the term "Multiple-effect Water-distilling Plant."

We are enclosing herewith a leaflet which illustrates a sextuple effect plant with preheater, condensers, etc. Two of these effects operate under pressure steam, one of them operates at atmospheric pressure, and the other three under a vacuum. Higher multiples than sextuple may be used if desired, in order to gain economy, but of course that increases the cost of the outfit.

I have recently received from our London, England, house a photograph of what we believe to be the largest water-distilling plant yet built. Same has a capacity of 500 tons of distilled water per twenty-four hours. It is an installation which our British house furnished to a firm in India. It is a sextuple effect, working in conjunction with a Babcock-Wilcox high-pressure boiler. If you

would like to have a photograph for use at the St. Louis meeting I should be pleased to let you have the loan of it, you undertaking, of course, to have same returned to us.

H. Austin.

STATE OF ILLINOIS

State Water Survey Division.

We referred your letter of inquiry to Professor Noyes, Head of the Chemistry Department, and I believe he has already sent you an account of the still used. Quite recently we determined the total solids and ammonia in the distilled water. The total solids averaged about 4 parts per million, the ammonia 0.076 part per million, total solids of the tap-water are 479 parts per million and the ammonia 2.88 parts per million. Since the still has been remodeled very little tap-water is used, but for the most part condensed steam from the high-pressure steam line is redistilled. Of course, the total solids in this condensed steam are not so high as in the tap-water, but the ammonia is practically the same.

Edman Greenfield,
Bacteriologist.

TOCH BROTHERS

New York City.

I am not much interested in distilled water outside of distilled water for laboratory use; in fact, conditions which interest me more are the production of pure water, not distilled, for large chemical operations.

I know one branch of the industry, however, that has trouble with distilled water, and that is the manufacturers of silvered mirrors. I think if you will write to some of them you will get some interesting information.

Maximilian Toch.

UNIVERSITY OF ILLINOIS

I am sending you under separate cover a reprint of an article describing our Chemical Laboratory, which contains an account of the still which we are using here. We have found this very satisfactory, with the exception that we found it necessary to increase the length of the portion of the condensing coil immersed in cold water. We have also arranged to feed the still with water

condensed from the superheated steam used in boiling the water in the boiler. In passing through the box used for preliminary heating of the water, the ammonia in the condensed steam is removed and we succeed in obtaining water which is nearly free from ammonia, although the water supply used at the university contains nearly 3 parts in the million of ammonia.

W. A. Noyes,
Director of Chemical Laboratory.

DESCRIPTION OF NEW LABORATORY, UNIVERSITY OF ILLINOIS

Distilled water is produced by two special stills designed by Professor Noyes. The new still, located in the attic of the new

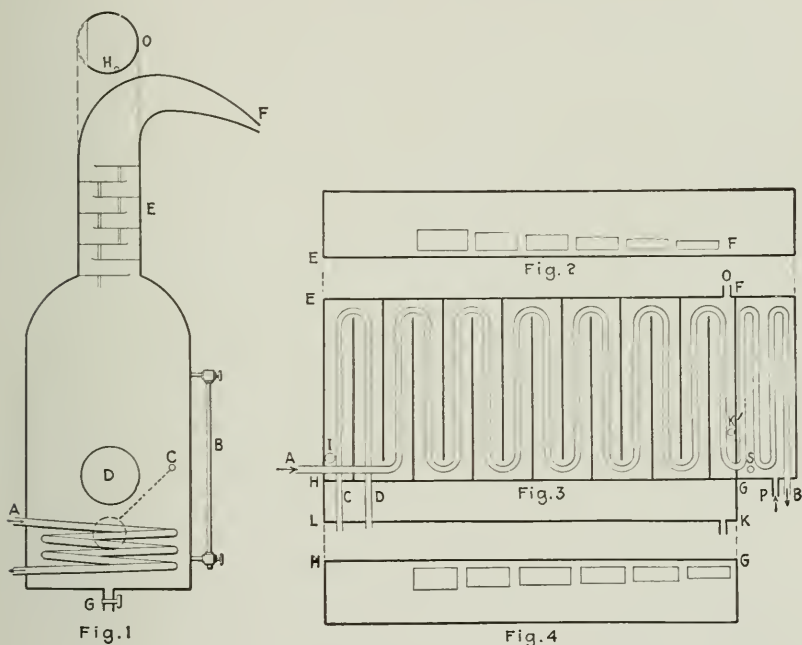


FIG. II.

building, is shown in detail in Figs. 1 to 4. The boiler, Fig. 1, is 36 inches high and 24 inches in diameter and is made of heavy copper. The heating coil A is a $\frac{3}{4}$ -inch copper pipe, 15 feet in length and connected with the high-pressure steam, G is a drain cock,

D an 8-inch manhole, *C* a constant level valve and *B* is a glass gauge. The head *E* is 20 inches high and 8 inches in diameter and contains 8 shelves, shown at *O*, each with a 2-inch opening arranged alternately to allow steam to pass upward. The edge of each shelf is turned up $\frac{1}{2}$ inch; condensed water runs back into the boiler through a tube, *H*, which rises $\frac{1}{4}$ inch above the shelf and extends within $\frac{1}{8}$ inch of the next lower shelf. The head is lined with pure tin and all soldering is done with pure tin.

The condenser box, shown in Fig. 3, is 12 inches deep, on the bottom of which is placed the $1\frac{1}{4}$ -inch tin condensing tube *AB*. The end *LE* is 4 inches higher than the end *GF* to give proper drainage. The successive partitions from *HE* to *FG* have a space of 2 inches at alternate ends, while *FG* is solid. The compartment *LHGK* is designed as a flue to carry off gases and steam to a ventilator with a strong draft. The sides *GH* and *EF*, shown in Figs. 2 and 4, have windows to facilitate the ventilation. *O* and the opening near *K* are drains. The box *LEFK* is covered, but the small compartment below *FG* is open. Feed-water enters at *K'* through a constant-level valve set to give a depth of 8 inches at *FG* and 4 inches at *HE*. As it passes back and forth across the box it is warmed by the condensation within the tube *AB*. The single coil *CD* is a 3-inch copper tube, connected with the high-pressure steam, permitting more thorough preheating of the feed water. The exit *I* is raised 2 inches above the bottom of the condenser box in order to leave behind any sediment. From *I* the feed-water passes to *C* (Fig. 1). The final condensation of the steam is effected in the compartment below *FG*, into which cold water passes through *P*. The overflow *S* rises 8 inches from the bottom. The distilled water leaves the apparatus at *B* and is stored in a heavily tinned copper tank which has a capacity of 2800 liters.

The feed water used is rain water from cisterns when this is available; at other times use is made of the water from the university wells which has been softened by the permutit process. An amount of alkaline permanganate is added, which is slightly in excess of the amount required by the oxygen-consuming power of the feed water. The capacity of the still is 80-100 liters per hour, but when running at full capacity the product contains somewhat more ammonia than is desirable. When running at the rate of 60 liters per hour, the nitrogen in the form of ammonia may be reduced to 0.06 part per million or less. The original water con-

tains 2.0 parts per million of nitrogen in the form of ammonia and 0.15 part as albuminoid ammonia.

VASSAR COLLEGE

Poughkeepsie, N. Y.

Replying to your inquiry about distilled water, I beg to say that we have no special appliances of note. Our general laboratory supply comes from a steam-heated automatic still in the attic. It is always slightly acid to litmus and contains a trace of chlorides. When these are objectionable, we prepare a special water in small stills.

Chas. W. Moulton.

J. S. YOUNG & COMPANY

Hanover, Pa.

Regarding the proposition of distilled water, would advise that in all of the laboratories with which the writer is familiar that are devoted to the manufacture of extracts there is a very large evaporating oven used with a constant water level for the evaporation of the tannin liquors. The steam outlets from this water oven are connected up with the condenser, and this gives the distilled water which is used in the laboratory under the writer's control, and those with which he is familiar.

We have no specifications for distilled water, other than when we use distilled water for water analysis, we take some of this distilled water and re-distill it in an old-fashioned copper, tin-lined still with a worm condenser, and it is my usual custom to take 5 liters of water, and add to this caustic soda and potassium permanganate and re-distill it. I throw away the first and last liters, keeping the 3 liters in between for water analysis, being careful that it does not respond to the Nessler reaction. I do not have any analysis of raw and distilled water covering gas content.

C. R. Delaney.

ASH GROVE LIME & PORTLAND CEMENT CO.

Kansas City, Mo.

At our cement laboratory, Chanute, Kansas, we have very impure water supply, and, therefore, also impure distilled water as shown by the following tests:

Grains per gallon, supply water	42.0
Grains per gallon, distilled water	3.6
Parts of chlorine per million, supply water	29.6
Parts of chlorine per million, distilled water	5.5
Parts of O to oxidize supply water, per million	13.83
Parts of O to oxidize distilled water, per million	0.67

The laboratory now uses what is called "Jewell's" still, made of cast-iron and heated by an open natural-gas flame. Previously the laboratory used a "Sargent's Automatic" copper still which is practically the same as the "Jewell."

A. Lundteigen.

COLGATE UNIVERSITY

Hamilton, N. Y.

In answer to your inquiries I would say that we prepare our distilled water by passing steam from a small boiler, the same as is used for house heating, into double-walled drying cupboard. From the drying cupboard uncondensed steam passes on to a coil of block-tin pipe immersed in a tank of running water.

We have found this combination of steam closet and distilled water apparatus to be fairly satisfactory, although cracks in the oven wall cause trouble from time to time. The expansion and contraction of the metal is so great that a soldered joint will not hold for a very long time. Therefore we would only recommend our system to others with certain qualifications.

I have no analysis of the distilled water and no recent analysis of the raw water, which is very good. We test the distilled water from time to time qualitatively, but we have not found it necessary to test it quantitatively, as there are no substances present which would interfere with our work.

R. B. Smith.

UNION PACIFIC SYSTEM

Union Pacific Railroad Co.

Omaha, Nebr.

Replying to your inquiry concerning methods used in producing distilled water, beg to advise that for our work on water investigations, we take a water that is obtained by a condensing system

from steam supply in the laboratory and re-distill this from glass, using distilling head and glass condenser. This gives us a water which shows total dissolved solids approximately 12 parts per million. In making hardness tests in our water supplies, we make an allowance for blank test on distilled water used.

W. M. Barr,
Consulting Chemist.

AMERICAN BRASS COMPANY

Waterbury, Conn.

The distilled water which we use in our laboratory is prepared in a Jewell Automatic Still. The water is distilled in a tinned copper vessel, the steam is condensed in a block-tin condenser, and contained in a tin-lined copper tank. The water is free from metallic impurities. We have made very careful tests from time to time to make sure of this fact.

The water for distillation comes from the public supply of the City of Waterbury. We have no recent analysis of this water at hand, and have no analyses of our distilled water. We know that the distilled water contains a certain amount of ammonia, but so far as our laboratory operations are concerned, it makes no difference, our only requirements being that it shall be free from metallic impurities and silica. Our laboratory work is almost entirely the analysis of metals and alloys, and we are not equipped for sanitary water analysis.

W. H. Bassett.

CORNELL UNIVERSITY

Ithaca, N. Y.

We employ the steam from our central heating system, passing it through a steam-trap and lead the so-called dry steam into a "Tripure Still" installation. The condensed water discharges into a large tank lined with block tin and flows by gravity to the various parts of the building through heavy block-tin pipe free from lead. During the summer months we generate our own steam in the sub-basement in a small upright tubular boiler, operating under 10 to 25 pounds pressure.

The installation we now have gives us water substantially ammonia-free and having a total solid residue of about 0.7 milligram per liter non-volatile solids.

Just prior to the fire we had installed an apparatus for measuring the conductivity of water and expected to use it in checking up the quality of the distilled water at least once a week, as this appeared to give us the most reliable indication of the satisfactory or unsatisfactory nature of the water supplied to our various laboratories.

Prior to this, all decisions as to quality were based upon the analysis of the total solid residue by means of microscopic chemical methods and after some ten years of experience we still think that it has given us the information we required.

In the course of our attempts to obtain distilled water of high grade, we obtained samples from friends in other universities and also purchased samples from druggists and from large plants. We found most of the samples examined of very poor quality.

Organic matter, volatile and mechanically carried in the steam, probably has caused us the most annoyance. For very careful work we re-distill several liters after acidifying with phosphoric or sulphuric acid, and adding a small quantity of permanganate. As a still we have employed large balloon flasks and pass the steam through a Hempel tube.

E. M. Chamot.

E. I. DU PONT DE NEMOURS & CO.

Wilmington, Del.

The distilled water used at this laboratory is obtained from tin-lined copper stills, the generators of which are 12×20 inches in size, and the coolers 6×34 inches. The cold, untreated water flows into the still until it reaches a stationary height regulated by an overflow drain pipe. The water is so heated by a steam coil that the generator becomes filled with steam at a low pressure. Four block-tin condenser pipes, opening at the top of the still, lead down to a single outlet pipe below. The steam, after filling the still, passes into these pipes and is condensed by the surrounding water. About 6 gallons per hour are thus condensed. The condensed steam flows into a 75-gallon tin-lined reservoir below, from which it is drawn off at the taps in the laboratories, as needed. Five stills of this type furnish the laboratory's supply of distilled water, and two more are under construction.

No rigid specifications have been formulated as to the quality of water for use. It must, however, satisfy four conditions:

(1) The residue on evaporation must amount to no more than a trace.

(2) The water must be neutral in reaction.

(3) It must contain a minimum amount of greasy matter, so as not to be objectionable for use with volumetric apparatus.

(4) It must be free from chlorides.

To make sure that no impurities get into the water, the reservoir tank is cleaned out very frequently.

Preparation

The apparatus for the preparation of distilled water is composed of a boiler of about 30 gallons capacity in which is inserted a steam coil at the bottom and at the top connection is made to a block-tin coil which is placed in a rectangular water tank that serves as a condenser. The boiler is made of heavy tinned sheet copper and has a water glass on the side and a relief valve on the top. The outlet of the block-tin coil is connected to the top of the storage tank for the distilled water. The capacity of the storage is about 70 gallons. The storage tank is made of heavy tinned sheet copper, has a water glass, and the outlet valve is connected at the bottom. All parts of the apparatus are of tinned copper or brass. There is an automatic arrangement similar to a flush tank fed by the main water supply for regulating the water supply to the boiler. When the storage tank is full the excess distilled water runs by gravity into this automatic feed tank. We have also a small tank connected with the distilled water tank to furnish hot distilled water. We find this hot water saves a good deal of time for the chemists.

Purity of Water

The requirements for the distilled water for general use are not very strict but in case water free from chlorine, ammonia, oxidizable substances, etc., is required, the chemist always re-distills the water for his own use. The following tests show the average purity of the water:

<i>Test</i>	<i>Found</i>
Ammonia and ammonium compounds.....	Small traces present.
Sulphates.....	Negative.
Nitrates.....	Negative.
Non-volatile material.....	0.0001 g. per 100 c.c.
Heavy metals precipitated by hydrogen sulphide.....	Negative.
Metals precipitated by ammonium sulphide... ..	Negative.
Metals precipitated by ammonium hydroxide..	Negative.
Calcium.....	Negative
Substances oxidized by potassium permanganate.....	Light trace.
Chlorides, calc. as chlorine.	0.0003 g. per 100 c.c.

Hamilton Bradshaw,
C. N. Whitney.

New York.

In response to your request of the 3rd inst. regarding distilled water, we may say that methods of preparing it vary according to the use for which it is intended.

For some purposes, largely technical, it is made by condensation in iron pipes.

For some purposes, such as in pharmaceutical manufacturing and dispensing, distillation and condensation in glass apparatus yields a suitable product.

For other purposes, such as the ordinary requirements of chemical analysis, determination of solubilities of sparingly soluble substances, etc., water condensed in glass or iron is frequently unsuitable, and recourse is had to block-tin or copper stills with block-tin condensers (without lead soldering), which are generally considered excellent for practical purposes. It is stated that traces of tin are sometimes dissolved from such condensers, but separate from the distilled water on standing a few days.

For still other purposes, largely experimental, silver and platinum condensers are used, but are, of course, rather expensive for producing distilled water on a large scale.

Distilled water for use in special chemical work, where entire freedom from nitrogenous and other organic matter is desired, is made by distillation from alkaline permanganate solution and condensation in glass.

Spring or rain water is generally preferred for obtaining distilled water, though even with these, special treatment is sometimes necessary. Magnesium chloride, when present in the water, is likely to yield hydrochloric acid. This can be prevented by addition of lime water before distilling. Sometimes volatile matter passes over into the distillate and after a few days yields a residue when the water is evaporated with acids. Such volatile matter can be removed, if desired, by passing the vapor over glowing cupric oxide before condensing. For some purposes ammonia is frequently eliminated by the addition of sulphuric acid, alum, alkali bisulphate, or similar material to the water before distilling. Distilled water for pharmaceutical purposes when desired specially free from odor is sometimes filtered, after distillation, through well-washed wood charcoal.

The testing of distilled water also varies according to the uses to which it is to be put. The United States Pharmacopœia gives tests governing the quality of distilled water intended for pharmaceutical manufacturing and testing. "Chemical Reagents: Their Purity and Tests" (D. Van Nostrand Company, New York) gives tests for distilled water suitable for testing chemical reagents. Many chemical and physical processes require distilled water specially free from one impurity or another, as organic matter, carbon dioxide, ammonia, etc. In such cases methods of purification and testing adapted to the needs of the individual case are applied.

OHIO STATE UNIVERSITY

Columbus, Ohio. ¹

The water distillation system in use at the chemistry building, Ohio State University, is located on the top floor of the building and the distilled water is carried through tin pipes to all the different laboratories. The water is used in all departments, including the freshmen laboratories, accommodating more than 1000 students, Industrial Water Analysis, Pharmacy, and Research laboratories. This requires a system that will furnish a relatively large quantity of a product of a high state of purity. Since the janitor takes care of the system, it further needs to be one that is easily operated.

The water used for distillation comes from the city supply taken from the Scioto River, and purified at the city purification

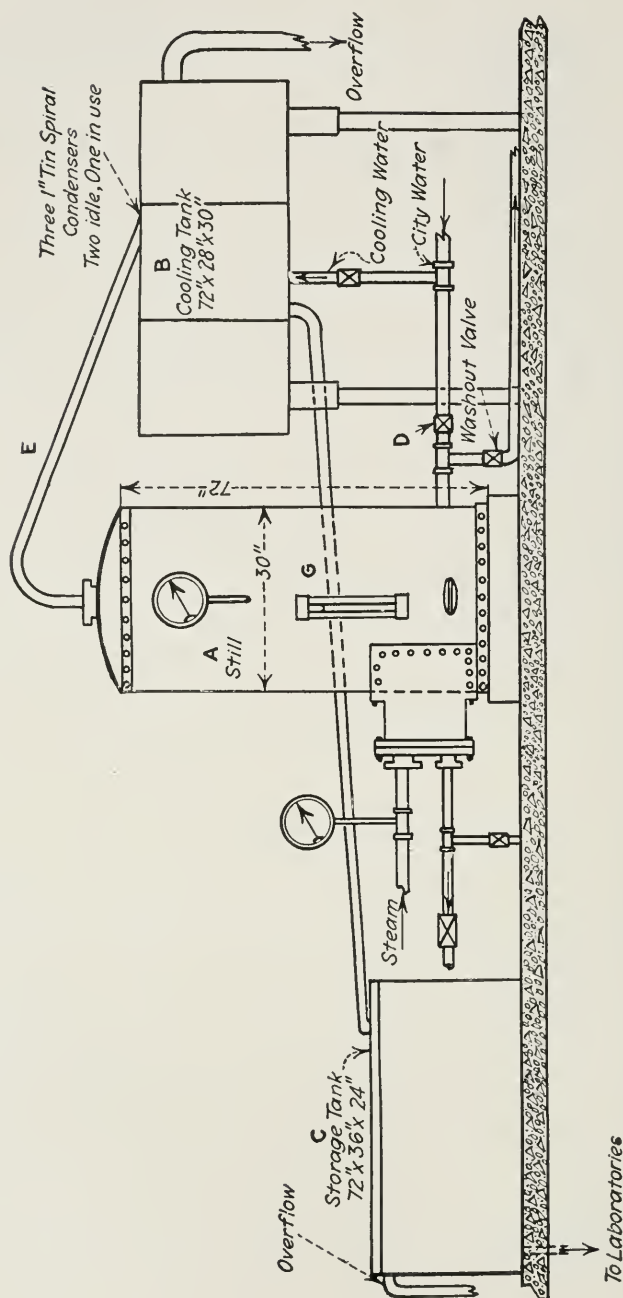


FIG. 12.—Water Distillation System. Ohio State University.

plant. The chief impurity before distillation is sodium salts. The organic constituents run very low.

The system now in use consists of a 30×72 inch vertical, iron shell ((A), diagram) fitted with steam coils that are surrounded by the water to be distilled. A water-gauge (G) on the side of the shell indicates the height of water in the boiler. As the water is evaporated the steam is conducted by means of a tin pipe (E) through a spiral tin condenser of 1-inch black-tin pipe, surrounded by flowing cold water in tank (B). There are three spiral condensers, only one of which is used at one time, the other two being held in reserve to avoid a stop for cleaning or repairs. Upon passing through the condenser, all steam is condensed and conducted to the tin-lined storage tank (C) from whence it is distributed by means of tin pipes to the different laboratories. All steam used to heat the water for distillation comes from the central power station operated by the University.

One disadvantage of this system lies in the fact that there is no automatic control of the height of water in the boiler. The height of water is controlled by the valve (D) which is closed when the water column in (G) is at the proper point. Trouble has resulted from inexperienced men allowing the valve (D) to remain open, thus permitting hydrant water to overflow into the storage tank. This, of course, necessitates a complete shut-down of the system to permit cleaning.

No systematic analyses of the distilled water have been recorded although frequent tests are made for sulphates, chlorides, ammonia, carbon dioxide, etc., and as long as the still is properly operated these run low enough for the work for which the product is employed.

H. S. Coith,
Instructor in Industrial Chemistry.

BERLIN MILLS COMPANY

Berlin, N. H.

We are inclined to agree with you that standard specifications for the purity of distilled water would be very desirable, and we will await your paper on this subject with interest.

W. B. Vanluskdel.

THE GRASSELLI CHEMICAL CO.

Cleveland, Ohio.

The distilled water apparatus which we use is practically the same as the water-still shown in Eimer & Amend's catalogue under serial No.E&A 2712—1913, water-still. We have modified this still by flanging the conical bottom of the still to the still proper in order to remove it easily and to make the bottom cooling coil accessible for cleansing. Also, we have further modified it by putting on a flange on the top of the still with a view of getting at the valve on the inside and repairing it with new gaskets whenever necessary. Another modification is that we have flanged the goose-neck to the still proper; this for the purpose of safety. We have put on a small pop-valve in case the still should develop excess pressure, to keep it from blowing up. We have put on a ball union to connect the goose-neck of the still to the condenser. This still produced water of a sufficient degree of purity for all industrial commercial laboratory purposes. We use the best drinking-water available in the respective communities in which we operate stills.

I give you herewith a technical analysis of water used here at Cleveland for making laboratory distilled water:

	Parts per Million.
Residue on evaporation.....	161
Residue on Ignition.....	130
Insoluble.....	51
Fe ₂ O ₃	2
Al ₂ O ₃	7
CaO.....	40
MgO.....	13
Na ₂ O.....	6
Cl.....	18
SO ₃	15
CO ₂	113

As regards the purity of water made, as before stated, this is of good quality for all ordinary purposes. It is not, of course, CO₂-free, nor free from some organic matter and ammonia; however, this is present only in traces. There is practically no entrainment of scale forming ingredients in the water made, as same is practically free of salts, as also sulphates and chlorine. In case

special water of high degree of purity is desired for certain specific purposes, it is made from ordinary distilled water in large flasks with glass stoppers and with fractionating column and condenser, and the water is previously treated to fix any ingredients it is desired to remove. The usual treatment consists of acid permanganate in case ammonia-free water is desired, or alkaline permanganate in case CO₂-free water is desired.

F. H. Lee,

Chairman, Mfg. Committee.

LOWELL TEXTILE SCHOOL

Lowell, Mass.

We formerly used a steam-jacketed copper still with an ordinary metal condenser. This troubled us at times by boiling over, so that some of the undistilled water went over with the distilled.

More recently we have installed a Barnstead Steam Still. We find that this gives water yielding no residue, containing no chloride, and only a slight trace of ammonia, and is satisfactory for all ordinary analytical work.

The analysis of the Lowell water, which is our city supply from driven wells, average about as follows:

	Parts per Million-
Residue upon evaporation.	45-50
Free ammonia.	.04-.06
Albuminoid ammonia.	.05-.07
Chlorine.	2.5-2.7
Nitrates.	.088-.181
Nitrites.	.00
Oxygen-consuming.	1.0-1.3
Hardness.	16-17
Iron.	.2-.4

L. A. Olnev.

MONSANTO CHEMICAL WORKS

St. Louis, Mo.

We are using distilled water for the quantitative analyses of raw materials and finished products, including the tests for U.S.P. requirements. The distilled water is obtained by condensation

of steam from our steam line, which is under pressure of about 100 pounds. A separator, made of pipe fittings, is used for elimination of oil and mechanical impurities and to take care of possible frothing; the steam is then condensed in a tin-coil condenser and the distilled water collected in a tinned-copper receiver.

We have no standard of purity for the distilled water, but we expect it to be pure enough to be suitable for U.S.P. tests, i.e., it must not give any opalescence on standing on addition of silver nitrate, of barium chloride (absence of HCl and H₂SO₄), and must not give a test for heavy metals. Our distilled water obtained by condensation of steam meets these requirements, but we found that by concentrating 20 liters down to 150 c.c., traces of Cl and SO₃ can be detected, and a quantitative determination gave

Cl.....	0.78 part per million
SO ₃	2.06 parts per million

On concentrating 5 liters to 100 c.c., traces of heavy metal could also be identified.

Our distilled water is therefore not absolutely pure, still we find it pure enough for the practical purposes of our laboratories.

You may dispose of this little information in any way you think best, with or without using the name of the Laboratory.

Jules Bebie.

PARKE, DAVIS & COMPANY

Detroit, Mich.

In making distilled water in our scientific work, as well as in certain of our manufacturing operations, particularly ampoule solutions intended for hypodermic or intravenous use, we employ an apparatus constructed somewhat as follows:

The water to be distilled is held in a main distilling chamber and heated with steam coils. Over this distilling chamber is a condensing dome, which is surrounded with cold water. On the inside of this dome near the bottom is a concave flange for collecting the drip, which is the distilled water, and which runs into a large glass receiver. On the top of this dome is a loose ball valve which equalizes the pressure and also, we believe, allows the escape of traces of ammonia, which are apt to be in the water. The water to be distilled is taken from our city water, which is Detroit River water plus a certain amount of chlorine gas.

We test the distilled water which we use in the Analytical Department for the absence of alkalinity by means of methyl red and cochineal solutions, and also for the absence of chlorides by means of silver nitrate. We have had trouble occasionally with traces of ammonia in the distilled water due to the accumulation of organic matter in the distilling chamber. This chamber has to be drained occasionally, and the organic matter cleaned out, which seems to do away with any trouble in this regard.

For special work in manufacture, all the distilled water is tested for traces of iron and must be absolutely free from iron.

Of course, the containers that are used for the distilled water as it comes from the still are especially washed in order to be sure that the glass is free from alkali and traces of soluble iron, as may readily occur in large containers, and furthermore, in the manufacture of such extremely delicate solutions as those intended for intravenous and hypodermic use, the distilled water is not allowed to stand for more than forty-eight hours before it is used, and is usually employed in less than twenty-four hours after it has been freshly distilled.

ARTHUR D. LITTLE, INC.

Boston, Mass.

In further reference to your letters regarding distilled water, we wish to say that our distilled water is prepared with a Barnstead still and piped through block-tin pipe into a covered tank lined with block tin. The water is drawn off periodically, and the tank cleaned, although we have never experienced any difficulty from impurities in the water. We do not get an absolutely pure distilled water, but an analysis of it made recently will show about what may be expected.

	Parts per Million.
Total solids.....	1.5
Inorganic solids.....	.6
Chlorine, Cl.....	.3
Free ammonia.....	.042
Albuminoid ammonia.....	.016
Nitrates.....	.000
Nitrites.....	.000

We consider this sufficiently pure for all ordinary chemical work. Of course, in water analysis, we re-distill this to get ammonia-free water. The Boston water from which we prepare the distilled water is a soft water running about 3 grains of total solids per gallon, sometimes as low as 2 grains. An analysis which we made from one of the reservoirs about 1911 showed the following results:

	Parts per Million.
Residue on evaporation.....	31.0
Free ammonia.....	.007
Albuminoid ammonia.....	.1110
Nitrates.....	.05
Chlorine.....	3.9
Hardness.....	.9
Iron.....	.17

It seems to us that the requirements for so-called distilled water must necessarily vary somewhat with the uses to which it is to be put: obviously for atomic weight work the highest degree of purity is necessary, but it would be a waste of time to apply such precaution to water for ordinary commercial work. On the other hand, it certainly, in our opinion, should be neutral and entirely free from suspended matter. The dissolved solids should be low and for water analysis it should be re-distilled to obtain ammonia-free water.

Roger Griffin,
Chief Analyst.

THE SOLVAY PROCESS COMPANY

Solvay, N. Y.

Referring to your recent letter, asking for information about our practice in regard to distilled water, there are no specifications or standard methods for the preparation of distilled water used at this laboratory.

The source of the raw water is Otisco Lake, which is the local municipa supply. This water is distilled in a Stokes Automatic Steam Heating Still, which has a capacity of 10 gallons per hour.

The distilled water is collected in a covered rectangular tank, which is lined with block tin. The tank has a capacity of 125

gallons, and is kept full. The water is drawn off into two-gallon glass bottles through a pipe at the bottom of the tank. The water from these bottles is then poured into larger storage bottles located at various points in the laboratory, from which it is siphoned for use. The still is cleaned every week, and the accumulated sludge is removed.

A. C. Houghton.

LELAND STANFORD JUNIOR UNIVERSITY

The system of distilling water for the general laboratory supply is by the use of a large copper still situated in the attic, and of a large Jewell still also in the attic. Each of these delivers into a large covered tank lined with block tin and connected with a distributing system of block-tin pipe delivering to all laboratories in the building. The faucets are of bronze. Distillation is by closet pipes containing superheated steam from the universal power house. We test only for chlorides, for general laboratory purposes—to make sure that no pinning or leakage has taken place. If such occurs, that still and tank of distilled water is cut off from the distributing system, and the other tank drawn upon until the contaminated tank is emptied to waste and cleaned. The water contains traces of volatile organic matter and shows ammonia by the Nessler test.

For special purposes copper stills are used with extra precaution as to purity—as, e.g., for sanitary water analysis when water is necessary, distilled until Nessler sol. gives no test.

M. Stillman.

Akron, Ohio.

The apparatus which we use in our laboratories for making distilled water is that made by the J. T. Stokes Company of the automatic type, with which you no doubt are familiar. City water is used, the source of heat being steam which is passed through a coil at a pressure of about 100 pounds. City water contains, from the chemist's point of view, a considerable amount of salt; this affords us a simple way of determining the purity of our distilled water. If, with the addition of a few drops of silver nitrate to the distilled water, no cloudiness develops in the water upon standing, the water is satisfactory for our purposes.

MERCK & Co.

Rahway, N. J.

Your letter of October 6th has been referred to me and I beg to acknowledge its receipt and my interest in the subject discussed.

I have not the data with which to make a formal report, but if an informal discussion in the light of my experience will be of any benefit, you are more than welcome to make use of any of the statements made below.

Undesirable Properties of Distilled Water. An odor often is perceptible in water that has been distilled and it is well known that a wash bottle filled with distilled water repeatedly and used in an analytical laboratory becomes greasy, on the inside, i.e., the film breaks, often in a very short time. Further, it is well known that distilled water has a flat taste and is toxic to such an extent that it is often unfit for bacteriological cultures. All these things lead to the belief that ordinary distilled water contains a volatile impurity or impurities of some kind, probably not present in the original water, and therefore a decomposition product of organic matter, most of which remains behind in the original still. This theory is further substantiated by the fact that if the distilled water is re-distilled from potassium permanganate, a very appreciable amount of the permanganate is reduced.

Remedy. The flat taste of the ordinary distilled water is destroyed by distillation from permanganate and even slightly improved by heating to boiling.

Properties of Water Distilled from KMnO_4 . Water that has been distilled from permanganate never causes the wash bottle to become greasy, and in the exhaustive tests to which Prof. T. W. Richards of Harvard has put water so prepared, in the course of his atomic weight work, it shows up as about the purest water obtainable. It is also proved by many observers, that the best water for conductivity work is obtained by distilling the already distilled water from permanganate. In all of this work, as in atomic weight work, condensation is carried out in block-tin condensers, as glass is known to be very appreciably soluble in water, especially where it condenses. We have therefore used water distilled from a small amount of permanganate, enough to give the water in the still a deep purple color and condensed the steam in a block-tin condenser. Such water leaves no residue on evaporation and gives no test for ammonia.

Charles Wadsworth.

MERRIMAC CHEMICAL CO.

Boston, Mass.

The laboratory still, as you know, was made from 8-pound lead in our own shop, and has been in continuous operation for five years with occasional replacements of the heating coil. Recently the lead coil has been discarded in favor of one of brass and no further trouble is anticipated from this source.

When first constructed, the vapor pipe was of block tin, but cracks developed so frequently that it was replaced by brass and has since been perfectly satisfactory.

The capacity of the still is about 2 gallons per hour. The steam consumption is small, the supply through a $\frac{1}{4}$ -inch valve barely cracked, being sufficient. The water is regulated to a small stream leaving the overflow pipe, the condenser being warm to the hand throughout half its length.

The condensate is collected in a 20-gallon tin-lined tank with gauge glass and faucet. The water is tested daily for sulphates and chlorides to detect leaks in vapor pipe or priming, and also occasionally with permanganate for organic matter which is present when leaks develop in the heating coil. It has not been found necessary to add permanganate directly to the still to oxidize volatile organic matter or ammonia, the water supply being practically free from such material.

Tests on tap-water and distilled water yielded the following results:

	Tap Water.	Distilled Water.
Absorbed oxygen	8 parts in 100,000,000	4 parts in 100,000,000
Total solids	86 parts in 1,000,000	1.6 parts in 1,000,000

The above water is satisfactory for our analytical purposes, except in case CO_2 -free water is desired, when it is boiled and cooled out of contact with the air. Stock solutions of silver nitrate and barium chloride have no turbidity.

The still at the *C* and *F* sets, I understand, has been run with drips from steam traps as a water supply. Under these conditions all scaling of the boiler was eliminated, but it was necessary to keep an excess of permanganate continually in the boiler to destroy volatile oils which were present.

There are also in operation in our laboratories one Stokes Automatic water-still fitted with a steam coil, one Barnstead

Automatic steam-heated and one Barnstead Automatic gas-heated. The quality of the water obtained has in every case been satisfactory, conspicuously so at the pieric laboratory where even the slightest traces of sulphates would vitiate our sulphate tests.

(Signed) R. O. Fernandez,
Chief Chemist.

RENSSELAER POLYTECHNIC INSTITUTE

Troy, N. Y.

The problem is an interesting one to us and the solution is not very apparent. For high-grade water we use the simple worm condenser attached to a copper retort and distil between limits. It is a nuisance, but we have no better method at our command. For the main body of our distilled water we use a Barnstead Automatic still, heated by steam. It's pretty good, but not entirely satisfactory and will not supply water free from ammonia.

W. P. Mason.

MARX & RAWOLLE, INC.

Brooklyn, N. Y.

Replying to you letter of the 5th inst. in reference to distilled water for laboratory use, we have been using for some years a steam-heated Jewell Water Improvement Co. Still of 3 gallons per hour capacity. The dome of this still is only a few inches from the bottom and unless carefully watched, there will be more or less contamination of the distillate entrainment. We have noticed this point particularly in Brooklyn, as the water supply until lately has contained at times as much as 70 parts per million of chlorine as NaCl, the water being obtained from wells a few miles from the ocean. The presence of so much salt made it easy to ascertain the purity of the distillate by making a qualitative test for chlorine with silver nitrate. Our experience shows us that distilled water is an unreliable product unless made under the immediate supervision of the chemist.

During the last few months Brooklyn has been drawing on the Catskill-Croton water supply. Chlorine as NaCl is only 3.5 parts per million and a qualitative test for chlorine is no longer useful. The same is true with regard to other constituents and we have been forced to rely on the weight of the residue on evaporation which

we try to keep below .0005 per cent. This is the limit given in Krauch's "Chemical Reagents." The U.S.P., 9th revision, is more liberal, allowing .001 per cent residue. We have not made any of the other tests given by these authorities.

A. C. Langmuir.

AMERICAN ELECTROCHEMICAL SOCIETY

South Bethlehem, Pa.

Replying to your request of Oct. 8, we have no specifications for our distilled water, so I cannot help you in that respect.

We simply take steam from our heating system (from a boiler house), condense it in a tin coil, and distribute it through the laboratory in tin pipes. (Tin solid, block tin.) It has been very satisfactory for over thirty years.

Jos. W. Richards.

TENNESSEE COPPER COMPANY

Copperhill, Tenn.

We use a Stokes Automatic Still of capacity of 1 gallon per hour. The still is heated by a steam coil.

The water is collected in a tightly covered block-tin tank, and conducted by gravity through block-tin pipes to different parts of the laboratory.

The water is neutral to methyl orange and contains less than 2 parts in a million of carbonic acid, as shown by phenolphthalein. One hundred c.c. evaporated showed no weighable residue, therefore total solids are less than 1 part in a million.

A. M. Fairlie,

Chemical Engineer.

UNIVERSITY OF OREGON

Eugene, Oregon.

In reply to your recent inquiry for information regarding the matter of distilled water in this laboratory, I will say that our requirements for this substance are not particularly exacting, and therefore we are able to meet them by the use of an improvised steam still, using the city water supply as a raw material. I will say that we are fortunate in having an unusually pure supply of

water for the use of the city and that we have no difficulty in securing distilled water supply from it which quite well meets our needs.

O. F. Stafford.

UNIVERSITY OF MICHIGAN

Ann Arbor, Mich.

I can only say that in this laboratory distilled water is used for ordinary analytical and synthetic work in chemistry and for work in physical chemistry. We have installed two Barnstead stills, each with a capacity of approximately 50 gallons per hour. These stills are heated with high-pressure steam coils and are in continuous operation, being supplied with our city water. This is a rather hard water, containing sometimes as high as 230 parts per million of total solids. The distilled water produced from the Barnstead stills is sufficiently pure for ordinary analytical or synthetic work.

However, when water of a higher degree of purity is required, such as is necessary for work of a very high degree of precision or conductivity work in physical chemistry, etc., we re-distill—in a special still designed in this laboratory—some of the distilled water as it comes from the Barnstead stills. This still used in preparing conductivity water yields about 60 liters. Some potassium permanganate and barium hydroxide is added to the water before distillation is commenced and the first 5 or 6 liters are rejected. This still yields about 45 or 50 liters of water having a conductivity of not more than 1.25×10^{-6} , and not infrequently this falls below 1.

The cost of producing distilled water increases so rapidly with the removal of the last traces of impurities, whether gases or solids, that it seems to me the degree of purity insisted upon must be largely determined by the use to which the water is to be put. The water used for any given purpose must be of such a degree of purity that any errors or trouble arising from impurities in the water itself should be very much less than errors or trouble arising from other unavoidable sources. If the distilled water used meets this requirement it seems to me unnecessary to insist upon a higher degree of purity.

E. D. Campbell.

Perth Amboy, N. J.

While distilled water made from direct steam (from the boilers) through a tin coil is mostly pure enough for ordinary use, it happens

once in a while that oil passes through the pipes and goes into the distilled water, also, even if seldom, iron (rust) from the pipes can be found, especially after repairing has been done in the steam line. We therefore use this water as a rule only for general laboratory purposes as washing glassware and other chemical apparatus.

For real analytical work we use now a water-still, the A. P. Link, Brooklyn, N. Y., still, which works by gas, and based on our city water gives a perfect distilled water, as all inner parts are tin and working open, and gases developed escape into the air.

For delicate work we therefore can recommend this still very highly. It costs about 2 cents per gallon for gas and furnishes about 1 gallon water per hour.

The works manager of the plant which uses the most distilled water reports as follows:

"We have two stills for the manufacture of distilled water, both stills condensing the steam from the boilers reduced to about 40 pounds pressure.

"*Still No. 1.* Is used for producing distilled water for use in the routine laboratory and renders a water quite high in purity, being free from chlorides and other injurious salts. This water will serve satisfactorily in majority of cases for analytical work.

"The water is produced by condensing the steam from the boilers by means of a copper coil, distilling into a stoneware receptacle.

"It is always necessary to blow out the lines thoroughly before collecting any of the water. This is done by allowing the water to run as waste until it is satisfactory.

"*Still No. 2.* Is of greater capacity and water is used for manufacturing purposes. However, this water has been found to be as pure as that produced by Still No. 1.

"This water is produced by condensing the steam from boilers at 40 pounds pressure by means of a block-tin coil, distilling into a large wooden tank.

"It is also necessary to blow out the line from the still as well as drain off condensed water from the lines before collecting the water for use.

"This water being collected in an open tank and in the factory, is subject to slight contamination. However, the same serves the purpose for which it is used and as was said before, is of quite high purity."

WELSBACH COMPANY

Gloucester, N. J.

For nearly thirty years we produced distilled water by single-effect copper still (tin lined), and obtained a very satisfactory product for our requirements, making no attempt, however, to remove ammonia, for the stills were regularly cleaned and condensers kept in good order, and water of high-grade quality was readily produced. In the early spring, however, when the Delaware River water, which we use, is cloudy by running ice, it is necessary to flush out the stills very frequently to keep the water of satisfactory grade.

For the past year we have been using a new still of 25,000 gallons capacity per day of twenty-four hours, when operated on exhaust steam, and a capacity of 30,000 to 35,000 gallons when operated on live steam at 60 pounds pressure. The still has two effects, and a large copper condenser, and we have located a cooler on the end of the system to lower the temperature of the water before delivering it to the storage tanks.

In this connection we might say that the temperature of the water when entering the storage tanks is considered to be a point of vital importance, especially if those tanks are made of wood, and if the distilled water goes into a storage tank at high temperature the total solids will be very much increased, even though the storage tank be an old one which has been in use for many years. I have seen the solids raised nearly 100 parts per million if hot water was allowed to fall into a wooden storage tank that had been in constant use for twenty years.

Everything is copper, tin-lined; the shells are of steel, also tin-lined. The catch traps are some of copper, tin-lined, and the rest of iron, coppered and tinned. The still is copper, guaranteed to produce water containing not to exceed 5 parts per million of solid matter, and under satisfactory operating conditions it easily produces water of this character. When operated at slightly lower pressures, so that the evolution is not quite so violent, the impurities in the water are substantially reduced. We occasionally have trouble with our system, but these troubles are usually caused by the loosening of a tube in the condenser, or some similar mechanical difficulty.

We pump distilled water through a brass tin-lined pipe, rubber and tin-lined lead. Whenever we use iron pipe, we have trouble

with iron being dissolved by the water, and this practice has, of course, been discontinued, and tin-lined pipe used practically universally.

Each effect of the still has its own water entrainer. Each effect drains automatically and a certain portion of this water is discharged so as to remove the sludge and mud. The water discharge, of course, always takes place through vacuum traps when the still is operated as a low-pressure still.

The water levels in the still are held by automatic valves, as is the steam pressure to the first effect. The output of water is 2.6 pounds of water per pound of steam, when operated as a high-pressure still, enabling the water from the first effect to be used. When operated as a low-pressure still, the condensed water from the first effect is thrown away, since it contains a certain amount of oil from the engine, and the output is then 1.6 pounds water per pound of steam.

The shells of the stills are constructed to withstand either a pressure of 100 pounds per square inch, or a complete vacuum.

The still has sight glasses and water-level glasses, cut off valves for each point, etc.

Harlan S. Miner,
Chief Chemist.

J. P. DEVINE Co.

Buffalo, N. Y.

We are attaching a series of drawings and will go over each one in detail, giving you some data, so as to make each one self-explanatory. The equipment used for the manufacturing of distilled water is made up in several classes, the first class being pressure multiple effect where units of triple, quadruple, five effects, six effects and even up as far as twelve effects are used, all operating under pressure, utilizing live steam from the boiler. With a triple-effect pressure distilled-water outfit, you can figure on about 3 pounds of distilled water from every pound of steam used, counting on using steam at 100 pounds pressure as it comes from the boiler. With a quadruple effect you get 4 pounds for each pound of steam. With a five effect, 5 pounds with a six effect, 6 pounds, etc., up to a twelve effect, where you would get 12 pounds per pound of steam. With a twelve-effect unit, however, it is advisable to use a higher pressure steam, namely, about 150 pounds. Sketch 2408 shows a

section through a double-effect pressure distilled-water outfit of ours, showing you the construction, namely, that of an internal basket of tubes, each unit complete with all of its necessary fittings, mountings, and auxiliaries and catchall and then finally going over into the condenser where it is condensed. Blue print 430-A is a field assembly of the same equipment that we show in cross-section on sketch 2408. The apparatus as shown on these two blue prints is capable of producing 40 tons of distilled water per day of twenty-four hours.

Sketch 1836 shows the triple effect unit on the same principle

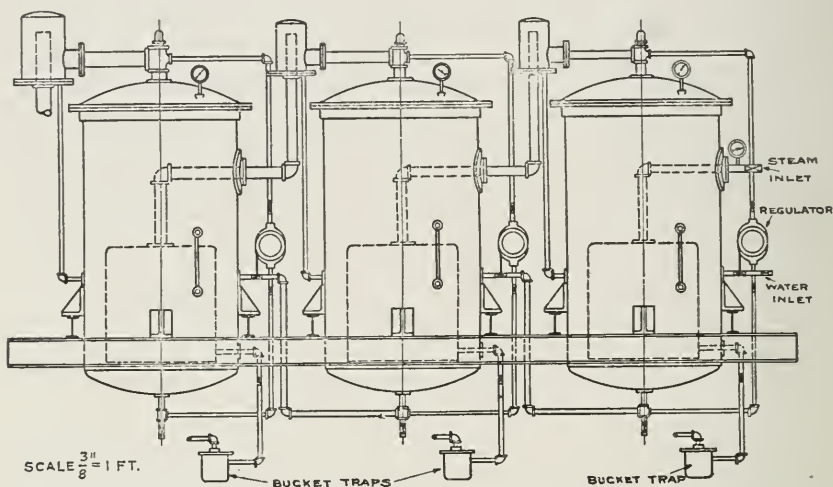


FIG. 13.—Devine Distilled Water System. Special Apparatus for Absorption Plants.

as the one above described, and blue print 430-X shows a twelve effect unit, which is made up of two rows, with six evaporators to a row.

We give you herewith detailed information as to just how this unit operates. Referring to blue print 430-A, which is a field assembly of a double effect evaporator, beg to state that: The raw water is spread either by gravity or by a feed pump through the feed-water regulator and into the first effect, from the first effect it passes automatically through another feed-water regulator into the second effect; these feed-water regulators maintain the proper level in both effects. The live steam is fed into the drum

or basket of the first effect, the vapors created in the first effect passing upward through the trap door and into the second effect. The vapors evolved in the second effect rise upward and out through the trap door and into the surface condenser. In this surface condenser it is condensed and goes to the distilled water tank, from which point it is taken and cooled. In order that you can procure absolutely pure distilled water it is necessary that the entire inside of the apparatus and the pipe-line through which the vapors come into contact are very heavily tinned. Where the requirements for distilled water are not very rigid, it may be possible to use the steam that comes from the boiler and if condensed in the basket of the first effect, this condensed water is taken out by means of a trap and can be sent through the same line to the distilled water tank. Where, however, the steam coming from the boiler may be contaminated with oil or other ingredients, like chemicals and the like, that is used in connection with water softening and where the distilled water must come up to a certain guarantee, then it is not advisable to send the condensed water from the basket of the first effect evaporator to the distilled water tank, but let it go right back to the boiler to be used as boiler feed. The condensed water from the basket of second effect, however, is pure distilled water, just like that which is coming from the condenser, so that the condensate from the basket of the second effect evaporator can go right into the distilled water tank.

In other words, where good steam is being used so that you can use the condensate from the basket of the first effect evaporator, you will be able to produce a greater amount of distilled water than you could where an inferior quality of steam was being utilized and so only making it possible to use the condensed steam coming from the basket of the second effect evaporator. In a triple, quadruple, five-effect, six-effect, and up to a twelve-effect evaporator, where steam of inferior quality is used, you cannot use the condensate from the first evaporator, but you can from every other one and from the final condenser. You will notice on our blue print 430-A that we show a tilt trap which is nothing else but a dirty water trap and which is connected to the last effect. This trap is necessary for the reason that it takes care of and automatically discharges the sediment that collects, which represents the impurities in the raw water being changed into distilled water. This trap can be set so that it can take care of various capacities

and fit in with local existing conditions. The apparatus as a whole is very flexible and is as fool-proof as any piece of equipment can be made, must just be set once and automatically taking care of the requirements imposed upon it.

There is still another type of distilled-water apparatus, and that is the type that is used when only exhaust steam is available; this would be where exhaust steam is only available, the apparatus could not operate under atmospheric conditions for the reason that you would have no different temperature, so must operate under vacuum. We attach hereto a copy of blue print 430-D-1, which is a field assembly of a double-effect distilled-water pressure and vacuum evaporator with auxiliaries complete and it so happens that we have a photograph of the installation as shown on this blue print, which will put some additional information in your hands.

We want you to note that this unit represents a very special condition that existed and which required special thought and study before the proposition could be finally taken care of. When going over this blue print you will, no doubt, see that the equipment is so arranged so that it can work either under pressure or under atmosphere. This was made necessary for the following reason: during the day they use steam that is exhausted in their engine, making the unit a vacuum unit. At night, when their engines are not running, they use steam coming direct from the boiler. This makes an admirable installation, as the outfit can constantly produce distilled water per twenty-four hours of the day, operating with exhaust steam when it is available and with high-pressure steam when the low-pressure steam is not available. In other words, you appreciate that if we were to put in a unit to produce a certain quantity of distilled water per day of ten hours, which is their day when exhaust steam is available from the engines, it would require an outfit twice the capacity as is shown. And the same thing applies if only used at night with the live pressure steam, so that in this outfit utilizing a day of twenty-four hours and different conditions, they have an apparatus that represents one-half investment of what a unit would cost operating with strictly low-pressure steam or strictly with high-pressure steam.

A. Dwitz,
Sales Manager.

THE DOW CHEMICAL COMPANY

Midland, Mich.

We use steam from our boilers which we condense in a block-tin condenser coil or worm placed into a water tank. The steam enters at the upper end of the coil and the condensate is drawn off at the bottom into a stoneware storage vessel. The lower end of the worm is also vented outside of the building. Cooling water is fed into the bottom of the tank and overflows at the top. The storage vessel is provided with an overflow and a draw-off to supply line to the laboratory.

We attach also a tabulation showing the composition of the water sent to the boilers and a test of the distilled water for impurities, from which you will note that we get a very satisfactory result by our equipment.

Distilled Water

Sample.	Treated Boiler Feed Water.	Distilled Water.
Total hardness.....	4.15 gr. per gal	
Perm hardness.....	4.05	
Total alkalinity.....	3.35	
Caustic alkalinity.....	1.70	
Chlorine.....	1.25	None
SO ₃	2.26	None
Total solids.....	12.20	
Dissolved solids.....	12.20	
Organic and volatile....	2.06	
SiO ₂	0.40	None
Fe ₂ O ₃ and Al ₂ O ₃	0.27	None
CaO.....	2.12	None
MgO.....	0.30	None
Na ₂ O.....	2.80	

Thos. Griswold,
Engineer.

CORN PRODUCTS REFINING COMPANY

Edgewater, N. J.

I wish to say that we distil water for ordinary laboratory work in a copper still heated by indirect steam, taking the precaution to discard the first part of the distillate, which contains volatile impurities. We also take care not to expose the distilled water to

any contaminations, such as dust or gases, for instance, ammonia, and muriatic acid, etc.

The distilled water used in preparing normal solutions is boiled before these are made up.

As a special precaution I have sometimes found that it is advisable to re-distil water in glass apparatus, using a small addition of potassium permanganate to the water before distillation, and, of course, taking all necessary care as to having apparatus and containers chemically clean.

I have no analysis of our distilled water, but have often made blank tests whenever I had a suspicion that impurities, such as, for instance, carbonic acid or ammonia, could have influenced the result of an analysis.

Chr. E. G. Porst,
Chief Chemist.

TENNESSEE COPPER COMPANY

Copperhill, Tenn.

Following is outline of our method of producing and storing distilled water.

We use a Stokes Automatic Still of capacity of one gallon per hour. The still is heated by a steam coil.

The water is collected in a tightly covered block-tin tank and conducted by gravity through block-tin pipes to different parts of the laboratory.

The water is neutral to methyl orange and contains less than two parts in a million of carbonic acid, as shown by phenolphthalein. One hundred cc. evaporated showed no weighable residue, therefore total solids are less than one part in a million.

A. M. Fairlie,
Chemical Engineer.

WORCESTER POLYTECHNIC INSTITUTE

Worcester, Mass.

We have two general water stills in our laboratories; one is supplied from the city high-service water and the other from the city low-service water, detailed analyses of which are enclosed. The water which is distilled from the high service is distilled out of a copper still provided with brass pipe through which live steam is passing. The distilled water is condensed in a tin worm and is

collected in a large 27-gallon Mariotte bottle manufactured by the German-American Stoneware Co. The distilled water used in our sanitary laboratory is distilled out of a somewhat smaller copper still, the water in which is heated by a brass pipe through which live steam passes, and this water is from the low-service supply. The water in the still is first treated with sodium carbonate and the first third of the distilled water which is condensed in block-tin pipe is rejected. All subsequent distillate is found to be ammonia free. This water is collected and stored in glass bottles. You will notice, however, that the total solids and volatile solids in this water differ in no respect from that which is used generally throughout the laboratories. Our laboratories use very little conductivity water and when this is desired we distill it separately.

Walter Louis Jennings.

Summary of Results of Analyses Made on Worcester Water

	High Service.	Low Service.
Turbidity.....	— 5	5
Odor cold....	slight, earthy	none
Odor hot.....	none	slight, earthy
Color.....	15	20
Total solids.....	57.0	40.0
Volatile solids.....	9.0	8.0
Free ammonia.....	.038	.016
Albuminoid ammonia.....	.130	.156
Nitrites.....	0.0	0.0
Nitrates.....	.480	0.0
Chlorine.....	2.45	3.43
Oxygen consumed at B.P.....	2.80	2.52
Hardness.....	26.0	11.6
Alkalinity.....	7.0	8.0
Silica.....	1.43	2.60
Fe and Al oxides.....	1.53	4.90
Calcium.....	5.22	4.46
Magnesium.....	2.72	2.00
Sulfate radical.....	12.40	4.30
Sodium chloride.....	6.60	7.40

Distilled Water

Total solids.....	6.25	6.25
Volatile solids.....	3.75	3.75

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Boston, Mass.

The institute has in use three kinds of stills at its new plant in Cambridge.

(a) The main supply of distilled water is furnished by a Barnstead steam-heated water-still and capable of furnishing about 40 gallons per hour.

(b) Several laboratories, which are some distance from the other chemical laboratories, are supplied from two small stills, a rough sketch of which is enclosed.

(c) Double-distilled water is furnished to the water and theoretical laboratories by digesting the ordinary distilled water with an alkaline permanganate solution and then distilling through a French column, consisting of three baffle domes, to increase the fractionation of the ammonia and other volatile constituents. This distilled water has been repeatedly obtained in quantities of 20 liters per day with a conductivity of 0.3×10^{-6} and is undoubtedly free from all solutes except carbon dioxide.

The following analyses were made just after your letter was received:

	Tap Water.	Still A. Parts per Million.	Still B.
Free ammonia.....	0.026	0.355	0.095
Albuminoid ammonia...	0.230	0.045	0.055
Nitrites.....	0.002	0.000	0.012
Nitrates.....	0.170	0.000	0.070
Chlorine.....	6.6	0.14	1.8
Dissolved solids.....	71.	4.	15.
Loss on ignition....	24.		
Ignited residue.....	47.		

A second analysis for free ammonia in the water from the Barnstead still was made after the tanks and pipes had been drained and refilled and it was then found to be practically free from ammonia, so that the value above reported seems to be unfair.

As long as considerable quantities of double-distilled water were always available, I think that I am justified in saying that the only test applied to the ordinary distilled water was whether it showed any cloudiness with silver nitrate solution.

The two principal criticisms of the stills of class B are that (a) they do not deliver dry steam to the condenser and therefore some of the original water is carried mechanically over into the condenser, and (b) it condenses with the steam all constituents, whose boiling-point is lower than that of water, the chief of which is ammonia. Both of these defects are eliminated in the Barnstead still.

OBERLIN COLLEGE

Oberlin, Ohio.

We use about 100 gallons of distilled water per week in all departments of this laboratory and find the one grade pure enough for all ordinary uses. This main water supply is obtained by condensing steam from the college central heating plant. The water supply of the town is moderately hard but has been treated by the town with lime and soda to remove excess hardness. The tap water thus contains some calcium and magnesium bi-carbonate and sulphate as well as chloride and sodium sulphate. This tap water shows a specific conductance varying from .05 to .006 depending on season and control of softening plant so that a quantitative analysis is hardly significant. No boiler compound is used with this water at the college heating plant and the steam passes through 600 or 800 feet of iron main before reaching the chemical laboratory. We pipe it in iron to the third floor and then condense the steam in a block-tin coil being very careful that all condensation in iron "riser" will return through it and not enter tin connecting pipe or condenser. Condensation is stored in tin-lined copper tank holding 200 gallons, and is piped to all parts of laboratory through block-tin pipe. Water from this supply tank recently showed specific conductance of .000007 and during the last year has tested .00004 or better. During summer months when the college heating plant is not in use we obtain water from a gas heated Barnstead still delivering about 5 gallons per hour. This recently tested .0000026, which is almost good enough for student use in conductivity experiments of an elementary nature.

Our heating plant operates on the vacuum system so that it is necessary to "suck" the steam into the condensing coils, but you are probably not interested in this detail though it is one that caused us some trouble at first.

J. C. McCullough,

Assoc. Professor of Chemistry.

DEPARTMENT OF COMMERCE

Bureau of Standards

Washington.

Before installing the distilled water plant in our new chemistry building, we tested distilled waters from various makers of stills designed for the production of distilled water for laboratory use, and found that the specific conductivity at 25° C. varied from $1(10)^{-6}$ to $5(10)^{-6}$ reciprocal ohms. The stills were of different types and capacities; some were gas heated, while others were steam heated. The ratio between the amount of distilled water obtained and the amount of water used in producing it was not determined.

The distilled water in our new laboratory is stored in a large tin-lined tank, and is piped through the building in block tin pipes. The unions and faucets were designed by Mr. McKelvy of this Bureau. The body of the faucets is cast from pure tin, and the core is of silver with tinned-in copper attachments. The distilled water which we use therefore comes into contact with tin and silver only. The average conductivity at 25° C. is $1(10)^{-6}$ reciprocal ohms, and the non-volatile residue runs below one-half a milligram per liter.

E. B. Rosa.

SYRACUSE UNIVERSITY

Syracuse, N. Y.

The ordinary needs of the laboratory are supplied by a still on the top floor which fills a reservoir that is tapped by blocked tin pipes leading to various parts of the building. The city water is boiled by high-pressure steam pipes in a copper still and is condensed in block tin pipes. The still has a constant level arrangement connected with the condensing tank. The whole thing was intended to work automatically, a float in the receiving reservoir being connected to the gate valves controlling the high pressure steam and the cooling water. This scheme was recommended to us by Professor Gill of the Institute of Technology, but we have found that the automatic feature required more attention than it was worth.

The distilled water made in this way has been ordinarily very satisfactory, but sometimes we have noticed white woolly suspended matter which came from the tin on the storage reservoir. Sometimes we have found more nitrites in this distilled water than in the city

water, and so far as I know the cause of the trouble has not been fully explained.

In order to make the "best water" for conductivity and for physical chemical purposes the distilled water is piped to a second still built of tin-lined copper and heated by high-pressure steam. An amount of alkaline permanganate solution is added to the distilled water in sufficient amount to oxidize all matter that may be present leaving the residual water in the still colored at the end of the distillation. The bottom of the still is funnel shaped and provided with a valve for draining off the residue. The upper part of the still narrows upward into a 6-inch column a foot high provided with sheet copper flanges for cooling the column so that the effect is that of a fractionating column. There is no constant-level attachment; on the contrary the still is always filled at the start to a definite level with the aid of a small vent on the side of the still. Steam is condensed in black-tin pipes as ordinarily, and the water is collected hot, the more volatile portion of the vapor being allowed to escape. We have always used non-sol bottles for collecting the water and they have been very satisfactory. We have frequently obtained from this still water with conductivity $.7 \times 10^{-6}$ reciprocal ohms.

H. C. Cooper.

UNIVERSITY OF KANSAS

Lawrence, Kansas.

The distilled water for the Chemistry Department of the University of Kansas is made from condensed steam from the heating plant of the University. The plant is very efficiently managed so that about 98 per cent of the return water recovered from the radiating system is used. Consequently there is very little hard makeup water.

The analysis marked "power plant" represents an average of several samples taken from the storage tank or return water. The dissolved gases will vary between large limits and it is possible that at certain times of the year the returned water will be completely saturated with oxygen.

The other analyses are based upon a series collected from the Organic Laboratory and the Chemistry I Laboratory.

C. C. Young.

REPORT OF WATER ANALYSIS—CITY OF LAWRENCE

University of Kansas.

Chemical Examination:	Power Plant.	Organic Laboratory.	Chemical Laboratory.
Oxygen dissolved	.0-50% Sat.	.0-100% Sat.	.0-100% Sat.
Nitrogen as free ammonia .05-1.5	.05-1.5		.05-1.5
Nitrogen as alb. ammonia .05-1			.05-1
Solids, total.	46.0	6.8	9.6

Mineral Analysis:

Fe ₂ O ₃ + Al ₂ O ₃ (iron and aluminum oxides).	None	None	None
Ca (calcium)	Trace	Trace	Trace
Mg (magnesium)	Trace	Trace	Trace
Cl (chlorine)	7.0	1.0	1.0
SO ₄ (sulphate)	None	None	None
CO ₂ (free carbon dioxide)	0-18	0-12	0-12
HCO ₃ (bicarbonate)	14.6	8.54	6.10

ENGINEERING IN CHEMICAL WORKS

By GASTON DU BOIS

Read at the St. Louis Meeting, December 6, 1917

The importance of engineering to the successful operation of any and all chemical works is such that it was deemed advisable to again start a discussion of the subject at this meeting with the purpose of reviewing the advance made in this field during the last few years and of getting an expression of opinion from the members of the Institute of Chemical Engineers.

During the last few years we have witnessed the gigantic development in this country of the organic branch of chemical technology for the production of explosives, dyes and pharmaceutical chemicals. The two last-named classes, dyes and pharmaceutical products derived from coal tar, are so closely allied that one cannot discuss the development of one without including the other.

The tremendous increase in the production of inorganic chemicals particularly of acids during the last few years was caused by the demand for the organic chemicals just referred to.

The engineering problems encountered in the manufacture of acids and heavy chemicals have been partly solved by the collaboration of engineers and chemists and while a more satisfactory solution of these problems is still sought and will continue to be the subject of extensive research, still the acid industry can be said to be more mature in this respect than the manufacture of organic chemicals. The acid chambers, the sulphur burners, the iron and steel apparatus, the roasting furnaces, the fans, caustic pots, etc., used in the manufacture of acids and heavy chemicals have passed the experimental stage and are now standardized to some extent. Acid men know what can be expected of the equipment in use and where it can be purchased. Without doubt there still remains a great opportunity for the application of individual ingenuity in solving general and local engineering problems of the industry, but this will always be the case.

In contrast to this situation we find the engineering problems confronting the manufacturer of organic products to be as manifold as they are intricate. They cover the whole range of problems encountered by the acid manufacturers; acids at various temperatures are used in the preparation of organic compounds, but we must also consider the peculiarities of the organic compounds themselves, their aversion for certain metals, usually for just those very metals which are best adapted for the construction of apparatus; we must consider the toxicity of the products which also influences the construction of the apparatus, then the volatility of compounds or of their solvents requires the attention of the engineer. In fact our engineering skill has to overcome not only the problems confronting heavy acid manufacturers but also those problems which confront distillers of alcohol, manufacturers of acetic acid and other products of wood distillation, crude tar distillers and manufacturers of various food products. When it is considered that our chemical problems are by no means "cinched" it will be apparent that we have problems enough to tax the ingenuity of any chemical engineer however skilled and experienced he may be.

How and where can the young chemical engineer acquire the necessary knowledge to deal with the problems confronting him, and if he cannot meet the exigencies of the industry, where can he find the necessary help to complement his lack of knowledge?

This very question has been the subject of many discussions. I have in mind the numerous conferences held by members of the Institute of Chemical Engineers and by other societies in an endeavor to bring before our university boards the necessity of special courses in engineering chemistry of a more practical nature than those given in former years.

Several institutions have now made strenuous efforts to comply with the exigencies of the industries but our country is still in a state of marked unpreparedness as regards the subject of my paper "Engineering in Chemical Works."

When dealing with the manufacture of organic products such as dyes and pharmaceutical products including the whole series of intermediates, we find an extraordinary lack of engineering knowledge and the poor chemical engineer is obliged to muddle through as best he can, learning as he goes by hard and expensive blows with practically no chance of assistance from mechanical engineers for the solution of those problems which cause the greatest difficulties.

We have before us, it appears to me, an important question pertaining to national economy. When costly mistakes are repeated year after year by successive classes of so-called chemical engineers, men equipped with the best our universities and technical schools can give; when such mistakes if added, sum up into millions of dollars yearly as the cost of completing the training of these men, it is but proper that we examine the nature of the mistakes in order to determine whether there is a way by which part of this expenditure can be saved by properly training the young graduates prior to their entrance into the industrial field.

Hundreds of chemical plants have been built during the last few years and in a great many cases young inexperienced chemical engineers were put in charge of the construction of some parts of these plants. This naturally applies mostly to the smaller plants started by the hundreds, many of which have already dropped out of the race but a few of which may yet become leaders in the chemical industry. However, our large plants manufacturing dyes and pharmaceuticals as well as intermediates have been obliged during the last few years, owing to the shortage of technical men, to make use of inexperienced chemical engineers, young and old, who were obliged to rely more or less on their good judgment for lack of any practical experience.

Let me in a few words point out some of the things these men were expected to do. We will admit that buildings for the proposed manufacture were available and that a certain manufacturing process, far from perfect of course, as manufacturing processes are wont to be, was available. Steam, electric power and water also on the premises.

Our chemical engineer first makes a plan of his plant, at any rate, I suppose he will. He realizes that sewers and drains must be laid; he had really never thought of this point before. He then excavates to place a few tanks underground, of course he does not think it necessary to test these tanks because they are new ones. The tanks naturally were found to leak after the plant had been in operation for some time. A tank with a stirrer is to be installed. There are so many kinds of stirrers and so many ways of supporting the stirring machinery. This is really more puzzling than he thought it would be. A handy man is consulted and the difficulty is finally overcome.

A 500-gallon vacuum copper still is to be installed for the distillation of acetic acid from a non-volatile organic compound, and as

our young engineer is unable to design this apparatus, all details are left to the coppersmith, who, of course, knows all about it. Unfortunately, however, the coppersmith, otherwise a really experienced man who knew by experience the size condenser he should use for the given capacity of 100 gallons distillate per hour, overlooked the fact that the distillation was to be conducted under vacuum and therefore the condenser he designed was much too small. Result, a large loss of acetic acid during the operation.

A filter is to be installed. The young man has consulted catalogues, looked over the advertisements in technical publications, and finally corresponds with various filter press manufacturers, who, he is advised, make just the apparatus he wants. He desired to filter four tons of calcium sulphate a day from a neutral solution. He finally chooses a side feed, open delivery plate and frame washing filter press because the cloths require no holes cut in them and furthermore a leaky cloth is immediately detected. This appeals to him. He needs three presses and four men for their operation, furthermore he has to install a receiving tank for his liquor and a pump to convey this liquor to the next apparatus. He might instead have installed, as he found out later for the same cost or even at a lower cost, one Sweetland or similar press which would have required one-third of the space, only one operator and which would also have obviated the necessity of installing the receiving tank and pump.

I will not follow our chemist's troubles any further, but simply mention that he has but a very vague idea of transmission machinery, does not know how to calculate gears, belts, shafts, etc. He is again puzzled when he has to decide on the size of his steam and water lines with the result that he will use 2" pipe lines when 1" lines would have been more economical and in fact better suited. At every step he stumbles, is obliged to accept the judgment of so-called "practical men" who often have no experience whatever in installations of this kind.

The result is, the plant is defective, the operation costly and wasteful and the results soon discourage those who had invested their money hoping to receive dividends at the end of a year.

It might be suggested that to place a young inexperienced man in charge of the construction or installation of apparatus is poor judgment, but on the other hand is there a better way of giving this man the necessary training and experience and particularly if he is properly coached and his mistakes are corrected by someone more experienced?

Teaching is an art in which our technologists are not necessarily skilled nor can they devote much time towards instructing the young recruits. Finally, the knowledge acquired by experienced chemical engineers comes from their own ability to observe and investigate the requirements of chemical plants; they are in this sense self-made men, and the young chemical engineer must not expect to be taught as in universities.

The facts are that the majority of the chemical engineers leaving our universities are perhaps good chemists, but certainly not chemical engineers. They hardly even possess the elements of chemical engineering as the term is understood to-day. Chemical engineers are to-day formed in chemical works only and nowhere else.

Columbia University and the Massachusetts School of Technology have post graduate courses in chemical engineering which are designed to turn out real chemical engineers, that is, as far as any school can do so in a reasonable time. Outside of these two and possibly a couple of other schools it can be said that we are not giving this important matter the necessary attention.

The truth is that with very few exceptions our university professors who are training young men for the industries do not by any means appreciate the importance of engineering to chemical works, nor the fact that a distinct branch of engineering is required, distinct from other branches of engineering. In other words, a chemist without special engineering knowledge cannot be expected to construct or successfully operate a chemical plant even though he have the help of mechanical or civil engineers and these mechanical engineers in order to be of real immediate value should have at least one or two years' special training to fit them for such work.

Recently some of my friends were discussing the manufacture of a certain organic product with a bright experienced professor who had worked out the process. My friends, realizing the difficulty of carrying out the process in any of the apparatus known on account of the corrosive nature of the products used, asked our professor in what kind of an apparatus he thought this could be done. The professor replied "That is very simple, in glass-enameled apparatus." He actually believed the problem was solved; the question of doing on a manufacturing scale what he had done in the laboratory was for him a very simple matter. He did not know how much money has been invested in glass-enameled apparatus which after having been used a day or a week was ready for the scrap pile. Glass enamel has

its usefulness without a doubt, but it is not fitted for hot solutions of either strong or weak acids and of course not for hot alkaline solutions.

A plant of this city manufacturing intermediates and organic synthetic pharmaceuticals has a total force of about 600 men. Of these from 200 to 250 are under the direct orders of specially trained mechanical engineers. These men are machinists, millwrights, pipefitters, coppersmiths, blacksmiths, carpenters, riggers and helpers. This plant therefore employs almost as many men in its mechanical department as it does operators and helpers in the manufacturing departments. This proportion of mechanics is probably a little above normal due to a large amount of construction work. These figures, however, demonstrate I believe better than anything else the importance of engineering in chemical works and when it is realized that neither the chemists nor the engineers leaving our schools are competent to direct this comparatively large mechanical force, it becomes apparent that we must endeavor to suggest a way out of the difficulties which naturally arise under the present conditions.

I have attempted to show that our troubles in the manufacturing field are at last 50 per cent mechanical; if this is the case we must keep pounding away at this vital problem, we must discuss it frequently; even though the Institute of Chemical Engineers has made thorough investigations and valuable recommendations for the advancement of this cause, I believe it is not superfluous to review the progress made by our educational institutions and determine whether we cannot drive our point further by new suggestions arising from a discussion of the subject.

Let me state briefly in conclusion what points in my opinion still deserve special attention.

If our technical schools are to turn out more competent chemical engineers, it is imperative that the teachers in these schools come to a better realization of the importance of engineering in chemical works. They must be made to realize that the successful operation on a laboratory scale of any chemical reaction is but the first step of a manufacturing process. This laboratory work represents possibly 25 per cent of the problems to be solved before the reaction can be carried out on a manufacturing scale. The engineering problems represent possibly 50 per cent of the difficulties to be overcome and the remaining 25 per cent is to be found in new chemical problems

arising in connection with the plant operation. All of the above does not yet take into consideration the actual management of the manufacturing operation which involves neither mechanical nor chemical problems but is more particularly an efficiency problem which frequently has to be solved by chemists and which I will not discuss in this paper, although it is just as important as the purely chemical and engineering problems.

Is it not the failure on the part of able chemists to fully appreciate the facts above stated, which has frequently been the cause of very large losses to manufacturers? Every one of us knows of examples which demonstrate this point. Therefore before students can be taught to appreciate the importance of engineering in chemical works, the professors and our university boards should be made to realize more fully than they do to-day that a chemist is not a chemical engineer, i.e., even an able chemist, without technical training, is not competent to design and install a manufacturing plant or to direct manufacturing operations. When the university staffs recognize these facts, they will impress upon the young students the importance of this technical training, and post graduate courses which have been introduced in a few technical schools and universities to develop young chemical engineers will then become the logical course to follow in all schools able to do so.

The second point which I wish to bring up is that we should endeavor to awaken interest in engineering questions as they affect chemical manufacture, by frequent discussions among chemists, by the publication of articles on special apparatus and constructional topics. While chemical processes are to some extent kept secret I see no reason why we should be as secretive on engineering topics. We have so much to learn, that we should be willing to impart to others, the little we know in order that we in turn may have the advantage of the experience gained by others. Americans have the reputation of possessing greater mechanical ingenuity than other people; let us, therefore, if this is so, make full use of this gift and develop it by team work for the benefit of our industries.

Germany possesses the well-known publication *Die Zeitschrift fuer Apparatenkunde*, which, as the title indicates, is devoted to the study of apparatus construction. Furthermore, the *Jahres Berichte der Chemischen Technologie* give valuable yearly reviews of the advancement of chemical technology including the chemical engineering branches. We have in this country to my knowledge no such

publications and yet the chemical industry of this country represents to-day a greater outlay of capital than does the chemical industry of Germany.

There is a third and last point which I wish to particularly emphasize.

I said in the first part of this paper that engineering problems encountered in chemical works had been solved by the collaboration of engineers and chemists. It is a fact that a chemical engineer is not competent to solve intricate mechanical problems. On the other hand mechanical engineers without special training are not fitted for the task confronting them in chemical works. Their training in chemical works entails expensive blunders due to their almost complete ignorance of the special features of engineering in chemical works. Here again much money and time could be saved if these engineers could follow special post graduate courses in chemical engineering, in which the special mechanical features of chemical engineering would be particularly emphasized. It should not be overlooked that there is to-day a demand for mechanical engineers with some chemical engineering knowledge. The two classes of men supplement each other and are necessary to the full development of our chemical industries. To the chemical engineer would devolve the duty; work out manufacturing problems, lay out the plant and operate it. The mechanical engineer would look after the construction of apparatus and their installation as well as upkeep and furthermore would attend to all power-plant questions.

I hope I have made this point clear, which is that it is not sufficient for us to train chemical engineers; we need specially trained mechanical engineers who can devote all their time to the important engineering features. This I believe is a factor which must be developed if we want to successfully compete in the world trade in chemical products.

DISCUSSION

The CHAIRMAN: This paper is now open for discussion. I would like to say a good deal about it, but I am going to let you have a chance to talk, so let us have it freely discussed.

DR. OLSEN: Mr. President, it seems to me that Mr. Du Bois has presented a very important subject to-night, and a subject that deserves discussion. We have had a good deal of discussion of this subject in the society but I do not think we have had

any too much, and I think we can stand a lot more. As I look at the situation, we have this condition—that we have a body of men who are in charge of our chemical industries and who are developing and operating them but who have been poorly educated, that is, they have been educated in the one subject only, and, as I sat here and listened to the paper I thought of the men who have been admitted to the American Institute of Chemical Engineers as chemical engineers. The applications all come to me. I read them through and note the education of these men, and I can classify our members into two distinct classes; first, men who have been educated as chemists with no education on the engineering side, or practically none. They have acquired such engineering knowledge as they have in the works by hard knocks after they left the college or the university. Then, on the other hand, we have a number of members who were educated as engineers, some mechanical, some civil or possibly in some other engineering lines, with very little chemistry. These men have gone out in the industry and have acquired a knowledge of chemistry. They were not taught chemistry in the college or university, and they are not as good chemists as they would have been if they had been taught, but they have succeeded because they have had some adaptability and fitness and have done some hard work after they got out of the college or university. In the same way, the men educated as chemists have acquired engineering and they are not as good engineers as they would have been if they had been properly trained.

There is coming now the third class filtering in in small numbers; that is a group of younger men who have taken the chemical engineering courses in the colleges and universities. Some of these men have had quite excellent training along chemical lines and also engineering lines. Now, that is the way this society has been organized, and that is the type of men who have carried on the work, but I think you will all agree with me and Dr. Du Bois that our chemical industries would have advanced much more rapidly, we would have been much earlier in the field if our technical men had had the proper balance between the chemical and engineering education.

Now, how is the situation from the point of view of the schools? Dr. Du Bois has touched upon that and emphasized that side of it, and I want to say that the schools are working on the problem just as the industries are working on their problems, such as the problem of men poorly trained. The schools have been making progress, as I think all will admit who have looked the matter squarely in the

face. There are at present over 2000 young men in our schools, colleges and universities and technical schools taking chemical engineering courses. There may be 2500, but it is something between 2000 and 2500 at the present time. Approximately a fourth, or a little less than that number, will graduate every year. Now, if you examine these courses in the colleges and universities you will find that the bulk of them are four-year courses, and you cannot educate the ordinary young man in chemical engineering in that time. Some of them have gone on to five or six years—Columbia, for instance, has a three-year graduate course, and the Polytechnic Institute of Brooklyn has a five-year chemical engineering course, and the Boston Tech has a five-year course. One of those years is devoted to passing the students around stations at selected industries. I don't know whether many of you understand this system, but I just want to present these two methods of solving the problem. The young men are given a number of weeks at each plant doing the routine work at the plant in the plant laboratory and studying the processes, and the engineering problems, as well as the chemical problems involved. Columbia University, instead of passing the students around, has adopted, so far as it could be adopted, the policy of establishing in the school suitable laboratories for the study of chemical engineering distinct and separate from chemistry or engineering, that is the two courses combined.

And now, the method which is presented to-night is that chemical engineering should be a graduate course. That is the suggestion as I take it from the speaker this evening, that there should be graduate courses in chemical engineering. That suggestion seems to me to be excellent in many ways. It is, that the chemist should get his four years' training, and that the mechanical engineer should get his four years' training, and then the two should be brought together afterwards in the same classes for studying chemical engineering. Now, that might possibly work out fairly well, although you will have in such classes men who know a good deal of engineering and very little chemistry, and men who know a great deal of chemistry and very little engineering, and you will be working on very different material, as I might call it. It might not be possible to carry on such courses successfully. But, it seems to me that an organization of this kind, consisting of a body of technical men who have had training in the college or university or technical schools, could certainly express themselves on one point, that is as to whether such

graduate courses would be desirable, whether it would be advantageous for men who have had the training such as you have had, to have had such courses. As I say, I doubt very much if it would be worth while to put different classes together, that is, men who are trained in such different ways.

I feel very strongly that the four-year course is not going to be continued, and that we must endeavor to place chemical engineering on the same basis and footing that the doctor of philosophy is placed, who has taken his college course of four years and then has taken his graduate work afterwards of, we will say, a minimum of three years, and has gotten his education, his advanced training or education in that way. Many of the older chemists were educated in just that way with a three-year graduate course and that graduate course was devoted exclusively to chemistry. Now, it would seem to me that it might be possible to devote three years to graduate work in chemical engineering. Whether the schools and colleges and universities are going to give doctor of engineering as a degree to distinguish these from the bachelor of science in chemical engineering, that is the four- or five-year course in chemical engineering, is an undetermined question, but it may be it will come to that.

The point that I wish to emphasize is the great importance of getting this problem solved. I also want to mention one difficulty from the educational point of view, which is a very serious difficulty. The chemical industries are expanding at a very rapid rate and demanding a large number of chemists. Two or three years ago we realized we needed more chemists and chemical engineers than we had. It was just as necessary for the colleges to expand and increase their output as it was for the industries to expand and increase their output. The men in the chemical industries could do that because you would figure in a commercial way and say, if we double our output we will double our income, and prices went up, and you had the money to do it. The colleges and universities can't do it. We had to go out and beg the money; it meant a certain capitalization of education and we couldn't do it except by begging it. That is one of the worst features of education to my mind; it is not put on a proper financial basis, and, while we saw the opportunity, and the necessity, and while we would like to do it, we can't get the money. We can't expand and get more students on account of the financial proposition, and there is where I think that popular sentiment needs to be educated, and I think there has to be a stronger realization of the

importance of this education and of solving the financial part of it so that the schools and colleges don't need to beg for it. I feel that the colleges and universities should come and with a perfectly straight face tell the chemical industry—we need a million dollars, gentlemen; we have furnished you a certain number of thousands of technical men who have made the industry, now we need to expand, and we need a million dollars. It seems to me that is a straight business proposition; and it seems to me from the point of view of the industry, it would be an investment which would bring big returns. You can't carry on the industry without trained men; you have got to finance it; you are taking a product, that is, the graduate of a technical school or university and you are taking that product away below cost. It costs a thousand, two thousand, three thousand dollars for every man graduated by the schools and the universities and the better the man the more it costs, and yet the industry does not pay him a living wage, and the college or the university or the technical school that puts him out, does not get a cent in return. Now, there is a justification for this method. The justification is that the raw material to produce chemical engineers frequently comes from families who cannot afford to pay the price, and we can't get suitable material to produce chemical engineers except out of families that often haven't the money to pay for it. It seems to me it is up to the industry to support the schools, and I think that is an important element in solving the problem which our speaker has presented to us to-night. (Applause.)

Dr. ANDREWS: I am inclined to agree with the stand taken by the speaker, which, as I understand it, is this: That the problem that we have to face with regard to the direction of the chemical factory is primarily a matter of organization. It is a matter of cooperation between the trained chemist who has some knowledge of chemical engineering, and the mechanical engineer, who has some knowledge of chemistry. Now, it seems to me that it is worth while to emphasize one of the most serious difficulties which I think has developed as an obstacle to that successful cooperation. It is this: It seems to be the natural tendency on the part of the mechanical engineer in chemical works to pass the buck in this sense—that he endeavors so far as possible to make the conditions of the chemical operation in question and the mechanical erection in question, conform to the convenience of mechanical construction, and it has come many times under my observation that a great deal of time has been

wasted because the mechanical engineer has not been willing to accept those conditions of the chemical profession which are absolutely and immutably set by the nature of the reaction itself. Take, for example, a reaction which must be carried on, we will state within certain limits of temperature. After the apparatus has been designed and finished, I will take, for example, experiments at some other temperature than that which the reaction requires, because, owing to mechanical features the reaction temperature is not considered necessary. In other words, he very often is inclined to scrap those conditions which have been laboriously ascertained as necessary by a long preliminary course of investigation and carry out what is really experimental work. I have seen apparatus where the charges are measured by contents instead of grammes, a sort of experimentation, which is exceedingly expensive, and sometimes even dangerous. Now, I bring that up, not as any reflection on the mechanical engineers. The tendency referred to is a tendency which every man has, to let as much of the burden as possible be carried by his neighbor, rather than on his own shoulders. The explanation is to be found therefore not in any peculiarity of the human nature of mechanical engineers, but by the fact that their study of chemistry has been so limited that they find it difficult to understand or grasp the necessary conditions that surround every chemical operation. It is for that reason necessary that in order that this cooperation be successfully carried out, the mechanical engineer must have enough chemical training to understand where his own duties begin.

Mr. MEADE: It seems to me that in the training of chemical engineers to-day, we are about where we were, at the time I was at college, in the training of electrical engineers. Doctor Olsen has just told us that the colleges all need more money. I am not surprised at that—we all do. When I went to college, I went to one of the poorer institutions. At that time electricity was just beginning to play the part which it does in the industrial life of to-day, and the small colleges as well as the large universities were asked to train men to fill positions in electric power plants, sub-stations, on electric railways, in charge of lighting systems, telephone lines, etc. The consequence was that practically all colleges made up an electrical engineering course, which was, at the smaller colleges particularly, usually in charge of the professor of physics. The electrical engineering students studied something about electrical machinery under him and then they went on to the mechanical engineering department and

took what courses seemed to bear on their work and so they were passed all around the college until, when they got through, they were supposed to be electrical engineers.

Now, in a way, we are doing pretty much the same thing to-day in chemical engineering with the result, I think, that we exaggerate the amount of mechanical engineering that a chemical engineer needs to know. I believe and still believe, that the basis of chemical engineering is pure chemistry, and I don't believe the chemical engineer can study any too much of it. At the same time he must know how to apply chemistry so that when he comes to the erection of a factory, he knows how to carry out on a large scale what the laboratory teaches him. But it does not necessarily mean that he must know how to actually design all of the apparatus which he is going to use.

For example, the mechanical engineer, who is building a power plant, will not attempt to design his own boilers and engines, but will purchase from manufacturers in whose design he has confidence. Similarly the chemical engineer who is building a works had much better trust the steel designer, for example, for the details of his buildings and the evaporator maker for the design of his evaporators, rather than attempt this work himself. After all, most of such design is the result of practice and ingenuity rather than theory—although the teachers don't like to admit it.

So, it seems to me that we could shorten up our chemical engineering courses a great deal by having a *specific* course in chemical engineering. By teaching chemists the mechanical appliances that are necessary to carry out their reactions on a large scale, and the underlying principles upon which these work, which, after all, will go back to physics and elementary mechanics.

There is no question about it that a man can learn more in seven years at college than he can in four. On the other hand, those three extra years at college might give him an academic rather than a practical way of looking at things.

Doctor Olsen has spoken of the value of the timber that the colleges get from the poorer farms, and the young men whose education represents a sacrifice on their part, and very often a much greater sacrifice on the part of their parents. Now, I think that a seven-year course, in many instances, would mean that these boys would practically be shut out of chemical engineering. This would certainly be a mistake and we all know too many instances of farmer boys who became famous to want to shut off such timber from the profession.

Another feature of the past that we are hanging on to is analytical chemistry. I still believe that students spend a great deal too much time on qualitative analysis and I think too that a great deal too much time is spent on quantitative analysis. Now, I have no doubt that the average man who has gone through college and has been taught the processes of chemical analysis—has been taught how to handle a burette and a balance, to filter, precipitate correctly, etc.,—can very rapidly pick up any analytical work that he may have to do. If we can take a bright man from our works, without technical training, and teach him in a few weeks' time to acceptably run our routine analyses, and in a little longer time even to do it intelligently, certainly the man who has had any training at all in the theory of chemistry and in practical laboratory manipulation can become proficient very quickly in this work. I have observed that no matter how much analytical work the chemical engineering graduate has had at college, he usually has to be taught the laboratory routine before his work is acceptable. So, I believe in chemical engineering, we could cut down on our analytical chemistry quite considerably and still come out all right. Some colleges are omitting organic chemistry from the chemical engineering course. This is certainly a mistake. The chemical engineer will soon have a broader field of endeavor in the organic industries than he now has in the inorganic ones.

Dr. FRERICHS: Mr. Meade, I do not agree with you. (Laughter and applause.) I believe if you take a man from your works and put him into the laboratory and expect him to make your analysis, you waste your own time. You want to take men from the university who have studied analytical chemistry, qualitative as well as quantitative, thoroughly, in order to save your own time and for that reason I believe that the course of qualitative and quantitative analysis as taught here in the United States in the universities and in the schools is none too much, and I say so realizing that the amount of qualitative and quantitative analysis taught here is more than they are taught abroad. I think this part of chemistry can never be taught too much, and the better they are trained in this respect, the better chemists they will make for your laboratory. (Applause.)

Mr. DILL: I would like to say amen to Dr. Frerichs. The course which I had in qualitative analysis I considered, and shall always consider, the most vital part of my chemical training. But that is not what I was going to say. The problem of getting a good chemical engineer, in my opinion, is something more than a problem in educa-

tion, because the man before he is a chemical engineer is a man and the quality which develops his value as an engineer is how much brains he has under his hat. And it has been my experience that the quality of a man's brain is of far more importance than the kind of education he receives, or how much of it he had, or what college he went to. I have in mind a man in a laboratory with which I am somewhat familiar. He is a young fellow about twenty-five. He was brought up on a farm up in the fields in Maine where they pry the sun up in the morning. His father was a wheelwright and machinist. His family is a family of pioneers that came into that country when it was a wilderness, and he has the sort of make-up that you can expect from that kind of ancestry. He went to one of those old-fashioned country academies, and that young man, with no college training, is considered by far the best investigator we have had in that department. He is working alongside of men who have had far more training than he has had, and who have been to universities with national reputation, but somehow that boy with his little education is the one who brings in the valuable results. And that is my first point—that the value of a man depends on his own inherent qualities rather more than it does on the training that is applied to those qualities by the university. That is one point. The other point is along the line of Doctor Olsen's remarks—there is a financial problem involved as well as a problem in education. I think the trouble with a great many technical directors is that they expect about a \$15,000-man, and they only want to pay him about \$2000, or \$3000 salary. (Applause.) And I think that when the chemical engineering profession can hold out rewards to young men that are comparable to the rewards offered by the mercantile branches, we shall have no trouble in directing to our chemical engineering courses in the colleges and universities just as able men as the engineering industries will need now or at any time in the future. (Applause.)

Mr. MOORE: Mr. President, I didn't intend to say anything now; I intended to listen to the discussion, but Mr. Meade is going to get a rise out of me. I know that I don't agree with him, I don't think it, but I know it. Now, perhaps, I can illustrate this by a policy that I have followed for several years. After keeping tabs on the amount of my time wasted by men coming into my laboratory who either knew too much wrong chemistry or not enough real chemistry, I made up my mind that I was following the wrong policy in hiring these undertrained men so I hit upon the following scheme. I went

to some of the colleges, one of them in particular, and said to the professor in charge of a course, "I want you to watch the graduating class and pick out a man to come to me when he graduates," and I told him the kind of man I wanted. I told him how much I would pay the man, which, when I started this, was \$75 a month. So, after the man had been found I said, "You will stay at the college and take another year's college course on problems such as come up in our mill." The point is here, gentlemen, if you get a man from a college and he only takes an hour of your time a day, that daily hour of your time a day is worth a great deal more than the salaries of several men. I said, "Now we will keep him in college a year and, during that time, he will be working on the problems particularly connected with our industry, those we are particularly interested in. The arrangement is that we will pay all the expenses and a certain amount for the equipment of the laboratory." The selfish part of it is that we take the professor's time instead of our own time. (Laughter.) Well, I tried it as an experiment. It worked fine, but as the experiment was conducted with only one man I realized that the success might have been due to the personal equation of the man rather than to the method employed. I tried it next year. I had two men. I got equally fine results. Still being the pick of the class, there was a chance then that it might be in the personal equation of the men. I went on, three, four, five and six men, taking the professor's time and not my time, and I got fine results from these men. I didn't have to go into the laboratory and tell them how to make a test of sulphur chloride or anything of that sort. When they came, they were familiar with the problems. But here is the question which comes right into that, which has not been discussed; there is a habit of throwing bricks at the colleges and at the professors, but do you realize the manufacturer doesn't know what he wants himself? (Laughter.) He expects or hopes for results which will save him money but he has a very nebulous idea of what he expects to accomplish and he goes to the college and says, "Here, send us a man to do this work;" he doesn't know what he wants himself and he puts the man at work, and the man, of course, makes mistakes. The manufacturer gets discouraged and the uselessness of chemists or chemical engineers to his mind is proven. I want to ask how a man, a new chemist, a chemical engineer, could have been persuaded to do what he was incapable of doing. I don't want to go into that now. (Laughter and applause.) Now, there are cer-

tain men that never will make good chemical engineers. If I tell a man, "Here is what I want, this is the problem that I want you to work out," and he comes to me and says, "It can't be done," I say, "Oh, your place is not in the analytical laboratory, or in the mill." I don't want him to tackle a problem with the idea that it can't be done. The very first failure that he makes is going to convince him that he is right and that I am wrong and that it can't be done. I want him to go on and study the problem. A pessimist never makes good. On his first failure, he always is convinced and, with the second failure, he is sure that he was right in the first place. (Applause.) Now, you want for a chemical engineer an optimist. Suppose it can be done. If he goes at it with assurance and believes that it can be done, he is much more likely to get it done than he is if he believes that it can't be done. He is not discouraged by the failures, which must inevitably follow the taking up of a new problem. That is absolute gospel truth.

Now, in relation to the mechanical engineer and the chemical engineer. The chemical engineer must, to a certain extent, be a mechanical engineer. He is having problems all the time where he has to design apparatus or plants. Now, here is a question of psychology. The mechanical engineer is an older man in the trade, the chemical engineer is a new man, consequently the mechanical engineer having had the greater value of experience and knowledge to back up his judgment, can, because of this experience put it all over the new chemical engineer. The chemist gives way to the man of experience, the mechanical engineer who, as a rule, is older experienced and usually older in years. Right here is a fundamental problem. In order to meet this the chemical engineer must know his laws of heat, he must know the first principles of construction, what are the tensile strengths of woods, iron and steel, what should be the pitch of rivets, the strength of cement and so forth. He has got to know some actual principles of mechanical engineering himself. So that when he goes up and gets the mechanical engineer to help him design his things, he can meet him on his own ground and show why the thing will or will not be a success in a given operation. Another thing, going back to the operation of this procedure which I outlined previously, and that is this: That there are too many chemists or professors in our colleges that don't know what the chemical or the mechanical problems are in the industrial world. One of my objects in my argument was that this proposition of training men in the institute as I proposed would

keep the college in touch with the new problems in the industrial world. I might say the proposition which I made these fellows was that, if they would take that year, I would start them at \$75 a month during that year at the institute but would pay them \$125 a month the minute they completed that course. That was one of the inducements.

I have asked, I won't mention any names, three different professors in one day a simple problem. I will give you the problem, like this: I said, suppose you have a vertical pipe and you put a flame in it, and suppose you burn that flame and get the air so that you are getting the exact required amount of air for complete combustion and let that flame run up through a tube so that you have complete combustion and the hottest flame and surround that tube with water so you have a calorimeter, and take another like tube burning the same amount of gas in the same given time and cut off the air supply so that you make a smoky flame go up that tube, instead of a colorless flame as before, which will, of course, be incomplete combustion, in which tube would you absorb the most heat? all three of these college professors who had kept their chairs warmed so many years, answered, that it would be the hottest flame with the hottest temperature. As a matter of fact, they didn't know the fundamental principles of physics and of Steffen's law that a colorless flame does not radiate heat, and simply the heated air in contact with the wall would give up its heat and the rest of the heat would be going up through the tube as hot air. In a luminous flame the luminants radiate heat to the walls of the tube irrespective of whether they touch the tube or not. Now, if those men had been in touch with smelting furnace processes or outside conditions in the world, they would have never answered the questions that way, and that is the kind of information, mind you, that they were teaching the graduating chemical engineers. It is the manufacturer of chemicals who knows what is wanted, and if he has a well-defined idea of what he wants himself, he will find no difficulty whatsoever in the colleges and the professors in cooperating with him in furnishing him what he wants any more than a man who goes out and makes things once known to a manufacturer, will have any difficulty in having the manufacturer make what he wants. (Applause.)

Mr. MEADE: I am afraid I have left you a little mistaken as to my meaning with reference to analytical chemistry. I am not advocating that you take a man from the works and put him in your

laboratories as your analyst. What I mean is that if we can take such a man from the works, as is being done by the various steel companies; if we can take such a man, who never saw the inside of a chemical laboratory, and, in a year's time, make him an analyst satisfactory enough to do routine work, why certainly men who have gone through four years at college and who have been taught the operations of analytical chemistry ought to be able to do that work after being shown.

Now, I appreciate the fact that this is not very nice to the man who has been already trained in college at his own expense to do that work, but, in spite of this the vast majority of American industrial laboratories are using many men as routine analysts who have been developed in their laboratories. I don't care how good a man is when he comes to the industrial laboratory, he has got to be shown the routine methods. So my idea would be not to eliminate analytical chemistry from the course or anything of that sort, but possibly we can cut off some of the time which is now devoted to analytical chemistry and give it to chemical engineering problems.

A MEMBER: Perhaps a little personal experience would lend a little light to this discussion, which certainly is a very interesting and a very important subject. I think the only man who ever thought he was a chemical engineer thought so when he was graduated. I don't believe that he ever thought so afterwards, and I don't think any college can turn out a chemical engineer. The college I came from establishes the same process. A man is not an engineer when he completes his four-year course. He is a bachelor of science. If he takes two extra years, he is a master of science. He is not a chemical engineer until he has served in the industrial world for a year in charge of some important work and established some important research which is accepted as beneficial to the chemical engineering profession. If you take a chemical engineer and set him to analyzing, you kill the engineer's profession.

I was making \$85 a month before I went to college. When I graduated from college, I hunted all over the country for a job; what they offered me was \$35 a month, \$40 a month and \$50 a month. I finally got a place at \$60 a month. The second day I was there the boss chemist came up to me and said, "Don't go any further." I said, "Why?" He didn't tell me further than that. The chief chemist tried to make me do routine analytical work just as some of our foremen are trying to make chemical engineers.

The gentleman over here made a remark which I am pleased to note, to the effect that the man in charge of a factory should take interest in a young man and give him encouragement and guidance. That is the thing that makes chemical engineers. Ninety per cent of the manufacturers to-day with whom I have had anything to do are too jealous of their own reputation. I do not speak of this personally, as I have always had the best of help from the people I have worked under, but 90 per cent of them will try to keep you from getting all the information you can for fear you will get a chance to get their jobs. Mr. Moore's plan is excellent, sending young men back to college and getting them interested in his problems and studying them in college. An engineer has to have the very best chemical training he can get, and the more training he can get out of college along lines which he can't get in the plant, and those are along theoretical chemical lines, especially physical chemistry, the better he is equipped to make a success of life. But there must be cooperation. You cannot make a chemical engineer in a college, and you can not make him in the works unless the two combine. The director in the works must cooperate with the college to teach the man and help him all they can. (Applause.)

Mr. MOORE: I forgot in making my statement to mention the fact that I started to state, and that was this, that these professors even after having been told the facts of that question did not believe it. (Laughter.) They said that it might be so, but they wanted to try it experimentally. They took a given quantity of gas which they burned to complete combustion with a temperature of 1500°C. , they took the same quantity of the same kind of gas and burned it with incomplete combustion by closing off the air so the resulting temperature was eight hundred and something, and heat to the calorimeter from the resulting smoky flame was $2\frac{3}{10}$ times that of a hot flame. They actually tried that before they would be convinced of things that they probably studied in their second year in physics.

In relation to the last speaker, I want to say, that I worked for a man by the name of T. P. Burgess. He said to me once, "Why didn't you do so and so?" and before I could answer he cried, "Now, I know what you are going to say. 'I didn't have any authority to do it.'" He said, "That is no excuse at all. 'Take the authority and if you are right, the company will back you up in it.'" Now, to-day, a man has got to have force of character to see things

through. He must accept and assume responsibility. There is nothing a superintendent hates so much as to have the works after he has got them running in routine fashion, whether it is good or bad, upset by a change in routine or method of operation. The chemical engineer, if he is any good at all, always upsets something. (Laughter.) Once when I was up at La Tuque this was impressed upon me very strongly. The gases were blowing off from one of the digestors. I took out my watch and began timing the blow-off operation.

The superintendent said there was going to be trouble and there was trouble. They were wasting there in the space of seven minutes the heat contained in 18,000 pounds of steam which could be recovered and utilized. This operation was repeated twenty times a day. To go on with the affair, I had men working smelting furnaces and so forth. The superintendent came along and took these men off and the operation stopped. I saw him and got them on again. The first thing something happened and the men were taken off again. I went to this superintendent and said, "I want to see you in the office." He came into his own private office, and I said to him, "Now, look here, I have been sent up here to do certain work. Now I am going to do that work in my own way, or I am going back to Berlin. I have been sent up here to do certain work and that work I am going to do as long as I am here." And, after that, after a good, plain talk with the superintendent, I never had a particle of trouble with him in the tearing down of the mill for the next three years even though changes in places cost more than \$100,000 and I blasted out one whole room from beginning to end.

Dr. ANDREWS: Coming back to that old flame proposition, it does not want to rest. It strikes me as a rather curious thing that Mr. Moore has clearly overlooked the fact that the result of the experiment depends entirely on the length of that tube.

Mr. MOORE: The length of the tube was expressed in the drawing.

Dr. ANDREWS: Not specified in the way in which you put the problem here.

ORGANIZATION OF CHEMICAL INDUSTRIES

By FRANK HEMINGWAY

Read at the St. Louis Meeting, December 6, 1917

There have been two misunderstandings with regard to this item on the program. First, a week or so ago I wrote to our worthy secretary that I should be unable to prepare an address on this important subject, and it was not until the New York train was approaching its destination in St. Louis that I learned that my name appeared on the regular announcement and that I was expected to at least touch on the matter. In the second place, I fear the title, "Organization of Chemical Companies," is wholly misleading, for it suggests promotion, charter, by-laws, and so on.

What really happened was that I spoke casually of a matter that has been uppermost in my thought for the past year or so; namely, *lack* of organization in many of the new large chemical companies themselves, and the necessity of bringing order out of chaos before going much further with the present attempts to bring about nationwide cooperative effort. The grouping of words to express best my subject would be, the "*lack* of organization in many of the newer chemical companies." Our president spoke last night of the difficulty of conveying in language the finer shades of meaning and of making clear to the audience one's own thoughts exactly, and I realize to-night after the visits we made yesterday and the talks I had with many of our members that what I am going to say may be of but little interest to many of those present.

Nearly all of you here to-night are engaged in established and already highly organized industries, and would be apt to class as "fairy tales" a simple and unexaggerated statement of just a few of the things that have happened in the last three years and are happening to-day, particularly in the industry with which I have been in close touch for some time past; namely, that of the manufacture of coal tar intermediates and dye stuffs.

Our visit yesterday to the wonderful plant of the Laclede Gas Light Company encourages us to believe that the manufacturers of coal-

tar derivatives in this country have little or nothing to fear to-day; or after the war in the face of world competition. But when we get to the next step; that is, eliminating the uses of the coke, the tower gas and the sulphate of ammonia, and consider what is done with those products described as coal-tar derivatives, we must acknowledge, if we are to be honest with ourselves that as regards the next two steps—first, the production of intermediates, and second, the manufacture of finished dyes, we are a long ways from home.

We may look with just pride on the wonderful progress that has already been made, but to employ a business term, the real progress is decidedly "spotty."

Nothing in the development of an industry of national importance is such a handicap as wrong-minded public action based on ill-informed public opinion, and I fear that the public generally, and indeed many members of the chemical profession itself, have based their opinion of recent developments on what they have read or heard of the successes made by those old-established companies which *have* made a success and of one or two of the newer organizations which have succeeded.

They have not had presented to them the long list of failures, nor have they any idea of how close to the wind many of the newer chemical industries are sailing to-day, despite the price advantages they enjoy. It is interesting and extraordinarily instructive at this time to read carefully the history of the failure of the British dye-stuff industry within a decade or so of the time of Perkins' discovery of mauve in 1856. The financiers and business men in those days blamed the chemist as being an impractical man, and claimed that what little success they had was due to their own efforts as business men and to the work done by their engineers. The chemist blamed the financiers and the business men, and indeed everybody but themselves, and they all joined in one general condemnation of their government. But one fact stands out; namely, that the most important factor of all was, as I have already expressed it, wrong-minded public action based on ill-informed public opinion.

However, we may claim to an extent that through the work of some of the members of this Institute, and particularly of men like Dr. Charles Hertzy, the American public is much better informed to-day than was the British public in the sixties and seventies.

I shall not touch at any length upon that subject which is uppermost in the minds of the members of this Institute; namely, the

ethics of the profession, beyond venturing to say, at the risk of making myself very unpopular, that a great deal has been done in the last three years without consideration to professional ethics and business honor. Capital has sunk many millions in enterprises on the advice of professional men who had nothing more than a book knowledge of the particular industry, and as a consequence capital to-day is not so entirely happy about the future of our great chemical industries as it would have been if all their advisers had governed their action by the code of ethics which this Institute has adopted, and although we have not caused these troubles, it seems to me that for the country's good we should do all in our power to correct them wherever possible.

Most of us have heard and used the expressions, cooperation, teamwork, and so on, until we are heartily sick of them. It has been my experience that business associations are formed with great enthusiasm, the heads of the important companies are all present at the first meeting, the officers are elected, committees are formed, days are spent over the by-laws, much is said about cooperation, and then the big men hand the thing over to their juniors and little further progress is made. We hear the same old platitudes and vintage bromides, and we know perfectly well that the same old competitive antagonism continues to a large extent.

Surely the head of the biggest corporation in the world, Judge Gary of the United States Steel Corporation, realized this when he instituted the Gary dinner. There is nothing illegal or in violation of the Sherman Act about men becoming first acquaintances and then friends. What happens when competitors become friends? Not necessarily an illegal price agreement, but a full, frank, honest and open discussion of their common problems.

In the first year of the war such a coming together would have been impossible. Had it been possible, there is no question that the aniline oil fiasco would have been avoided. Within an interval of a few months aniline oil dropped from exorbitant prices to less than cost.

I ask you would men with a knowledge of what was going to happen have deliberately entered the aniline oil business in those early days? Precisely the same thing happened in phenol.

This kind of competition is the greatest of all business disasters. It results in the closing of plants, the freezing out of the small men, the profitable continuation of the operation of the concern that is

financially very strong, and nine times out of ten as a result of such a business upheaval, with its attendant casualty list, no true technical progress is made.

Our German friends met their problem in a very different way. If a German manufacturer found himself undersold, he concluded that in all likelihood one of two things had happened, either that his competitor had a better and more economical method or was obtaining his raw material cheaper, and it seems to me that most of them never paused in their effort to simplify, improve and cheapen their processes.

Now, as I said in the beginning, all this may sound elementary, even rudimentary, to those of you engaged in fully established and highly organized industries. But I want you to realize that tens of millions of dollars are invested in chemical industries in this country under conditions that amount to chaos, and I ask you, is it right for us to view calmly the sacrifice of so much capital, so much plant and so much human effort, even though it may have been ill-directed at the start?

Many of you may think I am drawing the long bow when I make the unqualified statement that I know of many companies of large size whose boards of directors are composed wholly of financiers and business men possessing no chemical knowledge whatsoever, and in which there is no coordination between the directing head, the chemists and engineers, or chemical engineers, the sales department and the purchasing department. Companies hear that there is a good and profitable market for a certain product, and after a brief discussion with their head chemist, who, of course, should be able to produce any chemical product whatsoever (indeed that is what he is paid for), decide to start the manufacture, and as a result there have been innumerable instances of large companies that in good faith have entered into contracts for the sale of products which their chemists told them they *could* produce, only to make cash settlements after months have passed and the realization forced upon them that they were unable to produce the goods with the technical knowledge at their disposal.

Yet such concerns blunder along from one mistake to another, without taking the simple and obvious step of bringing about cooperation among their own departments and placing on their board the best and most highly trained technical men that they can find.

Surely a scrutiny of the directorates of the leading and successful

German chemical companies would at least indicate to these gentlemen that the success of the German industries had to a large extent been brought about by the prominence given in the management of their affairs to men of scientific attainments. It is hard to believe that with such conditions of complete lack of coordination or effort under their very noses in their own establishments, these very gentlemen will give time and thought to such matters as governmental action. It looks like getting the cart before the horse.

About two weeks ago I had the pleasure of entertaining Dr. N. O. Forster, Technical Director of British Dyes, Limited, and of bringing him together in a social and informal way with the heads of several of the important companies manufacturing intermediates and dye-stuffs. Dr. Forster spent a month in this country studying the development of the industry here, and as I understood him, with one thought in mind; namely, the future of the industry in America, in France and in England, and what was likely to happen after the war. He felt that in the fact that the countries of the allies could not possibly produce a full line of dyes before the end of the war lay the great danger, for the Germans would sell their small tonnage specialties to American buyers only when the buyers bought the full line. This condition is described in business "as full line forcing." There is a provision against this in the Clayton Act, and it seems that the crux of the whole matter will be in the enforcing of that provision.

To me it is evident that some of the larger companies in this country are practicing in their domestic trade the very evil against which they seek to protect themselves by legislation. We know of smaller concerns that are producing specialties that are a better quality than the same product manufactured by the larger companies making a fuller line, but are unable to place them under contract because the buyers fear to split their business lest the larger companies keep from them their fuller line.

This in itself is a delicate situation, which I maintain would be avoided with advantage to all had all the manufacturers come in personal contact and acquaintance ripened into friendship and led to free discussion.

I fear I have wandered from my subject, which has to do simply with the lack of organization in some of the newer industries, but I could not resist the temptation of touching on these other subjects.

To summarize the conclusions I have drawn from my observations in the last three years, I might say first that the members of such an

influential body as the American Institute of Chemical Engineers should individually do all in their power to hold the confidence of the public, the business men and the financiers in the development of the newer chemical industries, and to offset as far as possible the damage that has been done by the action of professional men not qualified to advise on particular industries, but who nevertheless have not hesitated to involve large sums of money in development. Second, that for the nation's good the individual members of this Institute should do all in their power, and without regard to their own pecuniary advantages, to educate public opinion, the business men and the financiers to a correct understanding of the problems they face, with a view to bringing true scientific and technical order out of the chaos which exists in so many cases, and to make clear in fact to some of the more complex organizations that although the solution of one technical problem is important, it is more important to first perfect the coordination of all departments so that finances, business policy, scientific control, utilization of waste products, sales and purchases, work together as a solid unit, to grapple and solve all problems presented.

DISCUSSION

Mr. DODGE: I rise with some trepidation, because I am not connected with the manufacture of these products, but I have had occasion in the last year and half to visit a few plants that have rushed into the manufacture of various things. Aniline oil is one. The people built plants with the idea of making some quick money, and scrapping the plants as soon as the prices fell. They had neither the chemical or engineering training that is necessary to successfully design and operate chemical factories, and, in fact, have made failures. Of course, the prices dropped, as Mr. Hemingway says, at times below the cost of manufacture with the present prices of chemicals. But surely it seems to me that there ought to be some method of governing these wild-cat schemes. I don't know how it can be brought about. I have had a little experience some years back in the manufacture of aniline oil, and the trouble then was that we had what was known as dumping to contend with from German sources. We knew what the Germans paid for the benzol, their nitric acid, and sulphuric acid. We knew what it cost them to make it, knew what their materials cost, and their labor was, but we couldn't sell it and make money, therefore, we quit. I knew of one company that

started out with a big plant; I don't know exactly what they make, but they make a lot of things. A friend of mine was offered a position as master mechanic at that plant. He was a capable man, master mechanic of a large plant now. He looked the plant over and could find nothing in the shape of plans of the layout of the plant. There was not a scrap of paper to tell where the pipe lines went. The president was neither a financier nor experienced in the manufacture of chemicals. The company is now in the hands of a receiver, which one would naturally expect.

The CHAIRMAN: The thought occurs to me that I may be able to connect these two papers. We talk of the chemical engineer. One of the things that we specify in our qualifications for membership in the Institute is that all candidates for admission to this Institute are expected to have expert knowledge of at least one branch of applied chemistry. A chemical engineer working along his everyday work can be a very good chemical engineer on certain work and be a very poor chemical engineer with regard to ninety-nine other branches. The same thing is true with regard to mechanical engineering, a man may be an expert mechanical engineer on fine die machinery but a very poor mechanical engineer when it comes to other operations. We think of the education which we want chemists to receive. As I see it, the only education they can receive is fundamental education, because they can't usually know the special education that they will require to fit them to go into special industries, with such exceptions as Mr. Moore has indicated where, after a man has graduated he takes another year to study the particular problems of the industry that he expects to enter. A student in a chemical engineering course that puts in his time on things other than fundamentals, unless he sees a particular line before him, is making a great mistake and wasting his time. Why should a man take up the study of all classes of distillation apparatus in addition to the principles of distillation which come in as a part of a chemical engineering course? The chemical engineer, when he comes from college, passes into the laboratory where he will do analytical work connected with the industry, then into practical operation, until he gets the knowledge of the art qualifying him to become a chemical engineer. I don't say colleges should not give the title or degree of chemical engineer, although there is a great deal to be said that a man's education is not complete until he has mastered an art in a practical way as we require in admission to this Institute. Take the case Mr. Hemingway has

referred to. It is clearly a case where men who might be competent engineers in certain industries have been engaged to design machinery for other unrelated industries, and, while they may be very good chemical engineers in one industry, they are very poor in the others, because—here is the fact that we are confronted with—all of our work is special work, there is not a man in this room that is not a specialist, and no good chemist can be anything else in these days. He may have two or three specialties. A physician we will admit can be a general practitioner, but, even amongst physicians, they have their specialties, and a man who is a good lung specialist is very likely to be a very poor kidney specialist. He may have had general knowledge on the thing, but he will connect all the trouble with the lungs instead of connecting it with the kidneys. I hope I have shown some little connection between the two papers, because I do thoroughly believe that the fundamental difficulty that we have in this question of education is that we try to make people engineers by *purely academic instruction*.

Mr. MOORE: In relation to Mr. Hemingway's paper, perhaps I could illustrate the point I made by a little chapter out of my own experience. In my younger days, I got up a process which has been successful in every place but one where it was put in. We were unusually successful with this process when we started it, so we organized a company to operate it in a city in Western New York. Where the process was successfully operating, we were paying \$5.50 a ton for coal, in the new location we got coal for \$1.75 a ton, and a better grade. We were paying \$4.40 a ton for salt, and in the new location we could get it for ten cents per ton, viz., the cost of pumping salt brine. We were paying \$6 a ton for lime, in the new location we could get it for about \$4.40, and as for labor, we were hard up for labor where the process was working, and in the new location labor was to be picked up begging because they had the homes there where the National Salt Company had bought up the plant and closed it down and people, having their homes there and wanting work, did not want to go away from their homes. Now, let's see what the stockholders did. Did they put on any chemical engineers as directors of the company, as Mr. Hemingway says? No, they put in seven directors, consisting of five lawyers, one saw bones, one tooth carpenter. When they organized the company, they got a man, a fine business man, a man that had taken a \$50,000-company and raised it to a \$1,500,000-company paying dividends. This was not such a

company as I heard some men organize in which one man told the other to be sure and not make the great mistake of running short of stock. He said "Be sure and have enough stock to sell." He said, "be sure and have stock in it." But this man had done the thing in a business way, and taken a \$50,000-company and organized it by a legitimate increase in business to a \$1,500,000-company. He became collector of the Port of New York, he was United States consul to Amsterdam. He was a good business man, they elected him manager. As a good business man he looks around and looks for engines and pumps and so forth. He gets an air compressor to compress; they had not been developed to the extent that they are now, neither had the gas engine. He found triple-expansion Corliss engines which were guaranteed to produce a horse-power hour on $2\frac{1}{2}$ pounds of coal given normal efficiency in the boiler, of course. He took it up with the best electrical companies, and found efficient dynamos all right. He was going to contract for these.

The dynamo and the engine combination was the heart of the whole proposition. We were getting our salt from the ground by means of pumps, pumping it up by means of an air compressor. He had a choice of two propositions there, either get a triple-expansion Corliss engine or to use a single-cylinder engine, and use exhaust steam to evaporate the brine for commercial purposes. Both good propositions. The directors heard of it and said, why there is one-third of the total capital being paid in going into engines and dynamos. What did they do about it? They sent a man around the country to the junk heaps and found that they could buy second-hand engines. They bought six engines, four of which did not run anyway and the two that did were slide-valve engines and very inefficient. One would run a 2-ft. stroke at 750 revolutions a minute. You can figure the piston speed if you want to. The bearings in another would melt out, the cross head would crack, everything went wrong. The engine would not run anywhere near capacity. It would never run four days in succession without having to be in the machine room. What they had picked out were not engines but junk heaps. This was what the lawyers, the tooth carpenter and the bone setter did. Well, did they stop there? Oh, no! They were resourceful men, they were, and when we wanted clay, fire clay to set fire brick with, they said, "What is the use of paying money for fire clay for fire bricks, we can take it out of the brook here." I kept tab on the fire clay. The actual cost of the fire clay from the brook

was just $2\frac{1}{2}$ times what we could have bought real fire clay for. (Laughter.) We put the furnaces up but the clay had iron in it and slagged in all furnaces—the bricks ran together and all the furnaces had to be taken down, so I had to buy fire clay for the furnaces after all. That is the way they did the operation. They did everything wrong, they did nothing right. They made this man who was a business man resign. There had been a lot of money subscribed on the condition that he remain general manager. The directors thought it easy enough to raise money on this operation and they proceeded to make their failure, but the minute he resigned all these people that had subscribed their money on that condition to have a good business manager, withdrew their money and the directors could not get other money to take its place. The engine that did run used $14\frac{1}{2}$ pounds of coal per horse power per hour instead of $2\frac{1}{2}$ pounds of coal per horse power per hour, and the expense of coal and so forth in a very short time equaled the original expense which the business man had proposed to pay for efficient engines and efficient dynamos. They did not utilize the exhaust steam for evaporation of salt brine. I might string out a whole list of agonies of this sort. Of course, I don't have to say the plant failed, it failed and failed gloriously. But in this particular place, the chemical engineer could have nothing to say about it. Well, I will give you an illustration of oil. I went down into the boiler room and found the oil salesman down there trying to sell oil to the engineer. Well, I did not make it known that I was present, and the oil salesman said to the engineer, "You know the Standard Oil Company has the finest chemists in the world. Now, do you know anything about the chemistry of oil?" The engineer said "no" and the salesman said, "I will explain to you. It is very simple." Then he began to explain to the engineer what the molecule was. Then he said, "A man must be very careful in the oil he uses because, in a good oil, the kind I would sell you, your engine would be running on roller bearings," and the engineer stood that all right. (Laughter.) He said, "What oil are you using?" and to the reply shook his head and said, "it is not as bad as some, but it is not a good oil, and I will tell you why. In an oil that I can mention, the molecules are triangular and they cut into the shaft. (Laughter.) In this oil that you are using, they are egg-shaped, and, as the engine hits them they turn up on end, causing binding and heating, but the oil that I want to sell you is made of perfect spheres and you get a

most beautiful ball bearing." (Laughter.) I laughed and made my presence known. The oil salesman got out the best he could. But the five lawyers, tooth carpenter and saw bones would not listen to me. As a matter of fact this oil he was going to recommend was a good oil but not better than the others except in price, for the particular use which was required. Nevertheless, the five lawyers, the bone setter and the tooth carpenter bought the ball-bearing oil on the recommendation of the engineer.

A MEMBER: I would like to make just one remark to get back to the subject again, which is a very good talk. The question is, some people believe that we ought to have more study and devote more time in school, and others don't. Now, I think someone said we ought to learn fundamentals. A friend of mine went into school and the first thing he asked the professor was what studies were best to take. The professor said, "What do you want to become?" and he said, "I want to become a mechanical engineer." The professor replied, "Take the electrical engineering course," that sounded awfully funny, but statistics show that in that college more who graduate as electrical engineers become mechanical engineers than men who graduate as mechanical engineers and vice versa. I don't think that we should spend more than six years of our life at college to learn the fundamentals. It is all we can ask, the rest must be up to the employer to bring men in his plant and teach the men the rest of it, and give men a chance to learn the rest of it. You men, all chemical engineers, I think it would be interesting if we should ask certain men what they have missed most, what they feel would have helped them most. I know from my experience, I have always regretted I did not have enough physical chemistry.

A MEMBER: One of the speakers mentioned that good sense and natural intelligence could make up for a lot of good education. I fully agree with him, but most of us are not fortunate enough to get along with that, we need a fairly liberal education to make good. Therefore, I believe that the problem of the chemical engineer is one of great importance, and well needs study and development. Doctor Thompson mentioned that the fundamentals are the most essential. I believe he is correct. Doctor Thompson added that it was not essential that a man should know how to operate a still.

A MEMBER: The purpose of the education of chemical engineers should not be to make them thoroughly familiar with the manufacture of phenol or any other chemical compound. I believe, however, that

the plan, as lately developed at Columbia University, giving the chemical engineer a course that makes him familiar with the most usual operations such as filtration, distillation is correct. Mr. Meade mentioned that it might work against the young fellow who does not have a chance to get such a full course. I don't think that will make much difference to the young fellow if he is ambitious and hard-working, and it would be certainly to the benefit of all. The other young fellows who do not have a chance to get that far in their studies will find plenty of opportunities in our big industries to make good, and, although it is not necessary to have thorough instruction in all this graduate work to be a splendid chemical engineer, however, if we can take such a course, I believe it will work out to the best for our industries.

I would also like to make a few remarks in connection with Mr. Hemingway's paper. Mr. Hemingway pointed out the many failures in the chemical manufacture of intermediates. I believe that the instruction given at Columbia and similar institutions where students use factory apparatus and learn how to carry out sulphonation and nitration, and where they are instructed in the difficulties in connection with the construction of apparatus in these chemical operations would make our chemical engineers more efficient and many of these plants would have succeeded, because they would have the talent to work the processes. They would have found the men familiar with such operations. I don't mean that they should know how to make TNT, but they would have been instructed in the fundamental operations and been aware of the difficulties in the apparatus and with the many mechanical and chemical features connected with the chemical operations. I believe many of these young industries could have succeeded if they had been able to obtain the necessary chemical talent.

In connection with Mr. Du Bois' paper, I would like to get back to the proposition of giving the chemical engineer and the mechanical engineer a chance to work together. I believe it would work out to the best for the industries. Doctor Olsen added the fear that it might not work well because they would be different, on a different basis. However, I don't think that would interfere with the successful working out of the plan. I believe, for instance, that fusions, sulphonating, nitrating, and so on, should be studied in these courses. If they would work together on one example for instance, the manufacture of phenol, or a similar product, in which chemical and mechanical

problems are met which the mechanical and the chemical engineer could solve, it would result to the interest and the benefit of both the men and the industry. The mechanical engineer would get enough chemical training to understand the chemical process and the chemical engineer would learn some mechanical engineering.

Mr. DODGE: There is one thing I want to say about this post-graduate course for chemists and mechanical engineers to make them chemical engineers. The chemist has got a chemical education, probably a good one, when he comes to take up the engineering end of the question. But he has got to study engineering problems. He has got to study the engineering part of the profession. His post-graduate course needs to be in mechanics, drafting and that sort of thing, and these studies will not do the mechanical engineer one bit of good. The mechanical engineer has got to be taught chemistry, he does not know the first thing about it, and his course must be entirely chemistry to explain to him why he can't go into a plant and tell the chemist that he must change the temperature at which the reaction has got to be carried out. If the chemist and the mechanical engineer are going to do a problem, the mechanical engineer must take the chemist's word for the chemical conditions, that is all there is about it. It is his business to design apparatus all right for those conditions, and not to tell the chemist to alter them, because it is easier to design apparatus to do it some other way. That is where the mistakes have been made. If you are going to have post-graduate work, it will require two absolutely independent and distinct courses. The men can work together afterwards, but they can't work together while they are getting their post-graduate courses.

Dr. ANDREWS: It seems to me that we are right up to the very important question as to what are the essentials of chemical engineering as distinct from chemistry. It appears to me that the courses that have been generally given in chemical engineering or in chemical technique are based upon an entirely incorrect system. In mentioning such course, the matter is classified according to the industries. It appears to me that such a course ought to be based solely on the nature of the operations performed and not on the particular industry in which those operations are used. In other words, the chemical engineer in the engineering operations of the course ought to be given to understand what the material resources are in the way of apparatus and machinery by which the laboratory operations for carrying

on a given erection must be followed, or to translate those laboratory operations into factory terms. In other words, the fundamental operations of the factory as carried on by condensers, filtration, distillation, fractional distillation, the operations of evaporation in single and multiple condensers, and so on, taking up those condensing operations and the various types of apparatus used. That is instruction which will be valuable to the man when he goes out into the factory, no matter what the particular lines of industry he may go into. This is instruction which never can be wasted and there is no portion of that instruction which he may not be called upon to use in any industry that he goes into, and it appears to me that his instruction in his engineering course might be confined almost entirely to a study of those fundamentals to large-scale operations. (Applause.)

SOME GENERAL ASPECTS OF EVAPORATION AND DRYING

By HUGH K. MOORE

Read at the St. Louis Meeting, Dec. 7, 1917

I have been asked by your committee to write a short paper covering the general subject of evaporation and drying without taking up any particular phase of the subject. The object in view, as I am told, is to either induce or provoke discussion of different phases of this important subject. The time at my disposal for preparation of this paper has been so short and the subject is so large that this paper, covering as it does the general subject of evaporation, must of necessity be lacking in the details so necessary to any particular phase of the subject and will not have the permanent value that is desired unless it leads to the discussion of certain aspects of the subject which might otherwise escape consideration.

If, however, this paper leads to the discussion of these aspects by those who have a special and intimate knowledge of them, then this paper will not have been written in vain and the time and energy spent thereon will not have been wasted, as the desire of your committee will then have been fulfilled.

The subject of Evaporation and Drying may be classified under six headings:

- (1) Direct Evaporation or Single Effect (Pressure or Vacuum);
- (2) Multiple Effect Evaporation;
- (3) Air or Gas Drying;
- (4) Radiant Heat Drying;
- (5) Chemical Drying;
- (6) Mechanical Drying.

The first is familiar to all of us and is used for instance in boiling water in a teakettle or evaporating water as in the production of jelly or candy, etc., and is still done in the most primitive manner, namely: putting the substance into a simple shaped vessel and heating it by direct heat. In this we have the primitive steam boiler.

The scope of this paper does not include either the history or the construction of the steam boiler, which was used as such by Hero, 150 B.C., for the production of power. We may, however, briefly consider the separation of two ingredients.

DIRECT EVAPORATION

Direct evaporation is used:

1. In cases where the amount of liquor is so small that it does not pay to have a multiple effect. An example of this is the evaporation of maple sap to make maple syrup, maple sugar, or candy either under atmospheric pressure or vacuum.

2. In cases when the boiling points are so high that multiple effect evaporation is not feasible; an example of this is the kettle process for caustic soda and caustic potash.

3. In cases where the liquor contains incrusting material so that it is necessary to clean the tubes or pan very often. An example of this is the evaporation of salt brine containing calcium sulphate.

4. In cases where a certain size crystal is desired. An example of this is the open drainer pan used in the salt industry.

5. In cases where the material to be evaporated is so corrosive that the materials required for the construction of the evaporator are too expensive to be used in anything but a single effect, of simple form. An example of this is to be found in the concentration of sulphuric acid, nitric acid, acetic acid, etc.

6. In cases where materials decompose at a high heat. Such an example is the production of concentrated coffee.

7. In cases where the object is to recover some volatile constituent. An example of this is the evaporation in the pot still. The evaporation in the column still is in this class, though it has certain features on the border line of the multiple effect.

8. In cases where the object is to obtain artificially a low temperature or a sudden chill. Both the absorption and compression systems of artificial refrigeration come in this class.

9. In cases either with or without vacuum where the liquor to be evaporated is already a concentrated solution and its physical or chemical properties require that the final dried product be taken off as a film or powder or mass of crystals. Sulphite digester liquor is an example; this may be best handled in a rotary drum drier either with or without vacuum, according to the product one desires.

Direct evaporation in a vacuum is practiced in nearly all the

above cases, though not, as many persons seem to think, for economy of steam, but rather to secure the advantages of relatively low temperature. It is found that there is no great economy in direct evaporation under a vacuum over and above evaporation under atmospheric pressure, and none at all if the vacuum has to be produced by steam power.

Chart No. 1 gives the values at different temperatures of the

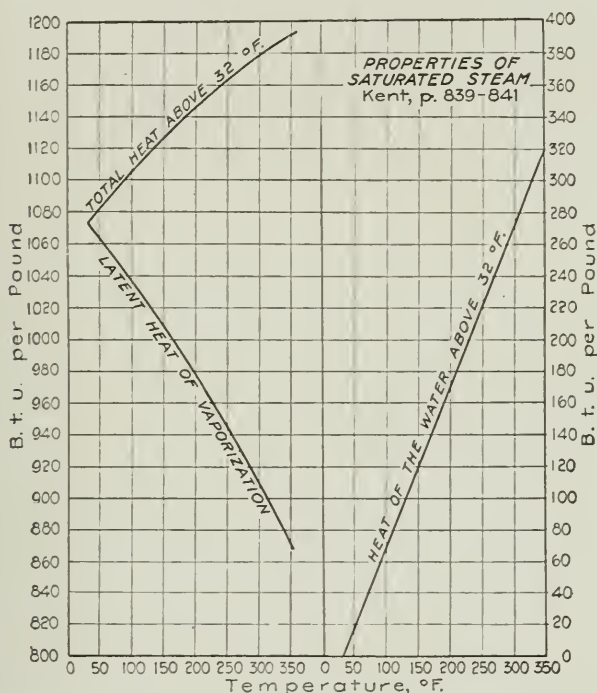


CHART I.

heat in a pound of water above 32°, the "latent" heat of vaporization, and the "total heat," or sum of the other two. Referring to Chart No. 1, 1 pound of steam at 212° F. contains 1146 B.T.U. (above 32°), while 1 pound of steam at 134°, namely under 25-inch vacuum, contains 1120 B.T.U. In other words, the pound of steam under 25-inch vacuum contains 97.73 per cent of the heat in a pound of steam at atmospheric pressure.

MULTIPLE-EFFECT EVAPORATION

Multiple-effect evaporation is distinguished from single-effect in that the vapors evolved from a portion of the substance are condensed in a separated chamber by another portion of the substance, thereby giving up their latent heat to this other portion and liberating their equivalent in vapor from this other portion. Each such stage is called an effect. It will be seen that each effect acts simultaneously as a condenser and evaporator.

For instance, referring to Chart 1, we find 1 pound of steam at 242° F. contains 1161 B.T.U. in total heat, 950 B.T.U. in latent heat. Theoretically if this steam heats water at 222° F., it should give up 971 B.T.U., evaporating thereby 1.007 pounds of water to steam at 222° F., having a total heat of 1154 B.T.U. and latent heat 964 B.T.U. per pound. This steam in turn could give an evaporation of 1.004 pounds of steam from water from and at 212° F. If we count also the available heat in the condensed water from the first effect we have .0103 pound additional evaporation. In other words, in the double effect operation as described we get 2.021 pounds of water separated from the liquor for one pound of steam used. Now the above figures are on a theoretical basis only. As a matter of actual practice the evaporation in the above illustration would be a little lower, on account of the heat carried off in the drip, or condensed water, which would not be reduced quite to the temperature of the evaporated steam as was assumed in the illustration.

It will be seen that this operation can be repeated as many times as desired, provided only that a temperature difference is maintained between successive effects.

This, in brief, is the principle of multiple effect evaporation. Later on in this paper the writer will explain a few of the intricacies of such evaporation.

The multiple effect principle is used:

1. Where the amount of liquor to be evaporated is large.
2. Where the cost or concentration of the valuable ingredients is so small and the cost of fuel is so high that the evaporating cost is an appreciable item in the whole operation. As a matter of fact, multiple effect evaporation is very seldom resorted to on a small scale, because the required constant attention of an expert evaporator man usually more than offsets the saving in fuel.

Furthermore the first cost of a small multiple effect evaporator is all out of proportion to the work done.

AIR DRYING OR GAS DRYING

Air (or gas) drying is a method of evaporation in which the partial pressure of the vapor of the volatile constituent is kept less than the vapor pressure of the liquid by mixing with the vapor air, or other gas. In this case the pressure shown by a gauge is

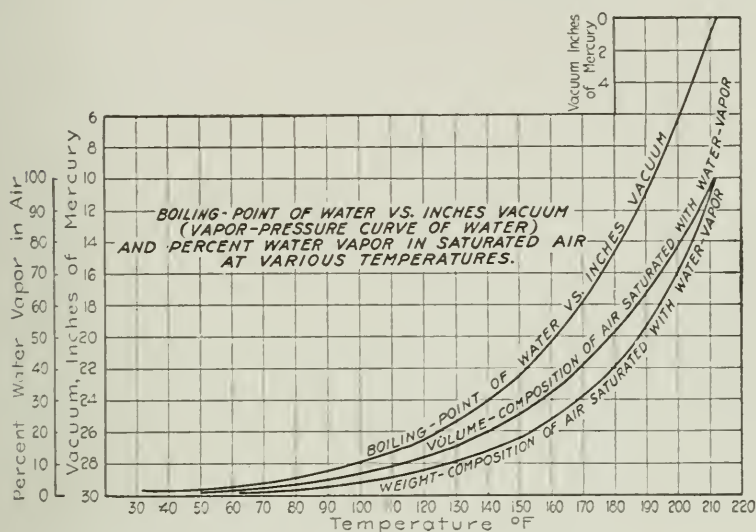


CHART 2.

the total pressure, or sum of the partial pressures of vapor and air.

Women know that they can dry clothes on a fine day even though the temperature be below freezing. They can also tell you that if the wind is blowing briskly the clothes will dry much more quickly. Here then you have a common case of air drying with which everyone is familiar, though few could tell how it is possible. The curves on Charts 2 and 3 show the vacuum required to produce boiling compared with maximum per cent water vapor in air at the same temperature. On this chart will also be found the relation to temperature. Thus, air at 187° will take up additional water only if it contains less than 60 per cent by volume of water vapor, and

water at 187° boils only if a vacuum of 12 inches is exceeded. Then at 187° air containing 60 per cent water vapor may be said to correspond to a 12-inch vacuum. At 195° air containing 60 per cent *by weight* of water vapor corresponds to a 9-inch vacuum. Again, saturated air containing 10 per cent water by volume corresponds in temperature to 27 inches of vacuum (115°). It will thus be seen that by decreasing the proportion of water vapor in the air the temperature effects of any desired vacuum can be obtained without the necessity of maintaining a real vacuum in a closed apparatus. A given volume of air if maintained at a given temper-

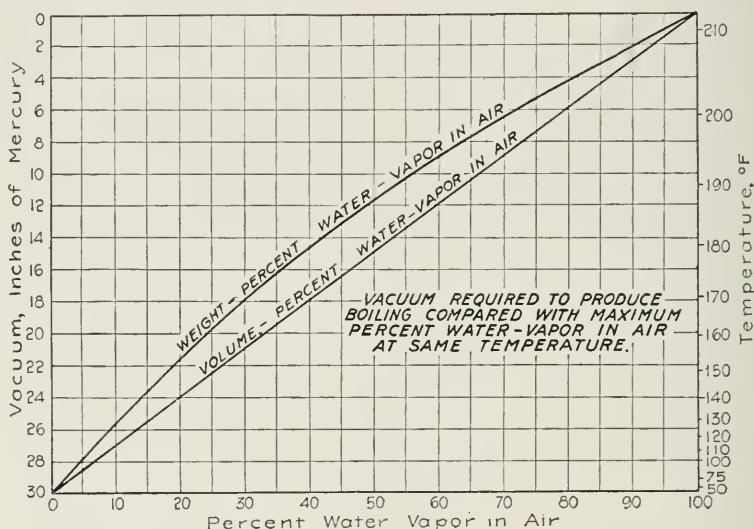


CHART 3.

ature can only evaporate a certain maximum amount of water (or other fluid) and this limit is only approached when the air has been brought into intimate contact with the substance to be evaporated, so that all parts become saturated. Of course it goes without saying that the hotter the air and the drier the air the more rapid the evaporation. However, increasing the temperature of the air does not increase the temperature of the wet substance very greatly if the percentage of saturation is kept low enough. One pound of water requires about 1000 B.T.U. for its vaporization whether it be evaporated under pressure or in a vacuum. Now in every case the necessary heat must be supplied, either from the

air, from the substance being evaporated or by conduction to the substance being evaporated. It should be remembered that heat is relative and things we consider cold may give up heat to things which are colder. It may be asked where the heat comes from that evaporates the water in clothes hung out to dry on a cold winter day and what difference of temperature there could be. Perhaps this can be answered graphically by the curve of Chart 4, which shows the cooling effect of dry air, based on wet and dry bulb thermometer readings, also Chart 5, showing pounds of dry

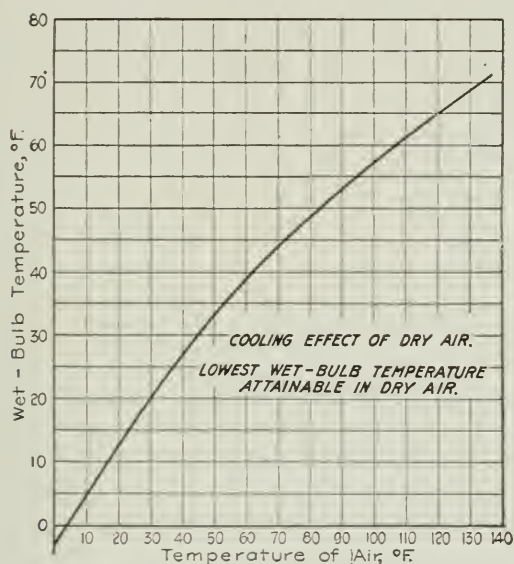


CHART 4.

air required to furnish heat to evaporate 1 pound of water at various temperatures. Chart 6 shows pounds of water per pound of air and pounds of water per pound of mixture when air is saturated at different temperatures. For example, Chart 4 shows that with dry winter air at 30° F., the clothes could drop to a temperature of 20° and Chart 5 shows that 470 pounds of dry air at 30° would contain enough available heat to evaporate one pound of water at 20° F. This assumes that the air is originally dry and leaves saturated. If, however, the air is not dry and does not leave saturated, a greater quantity is required. It will be seen that

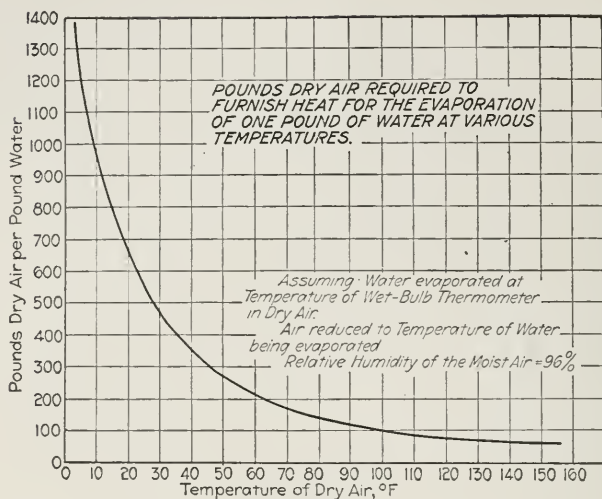


CHART 5.

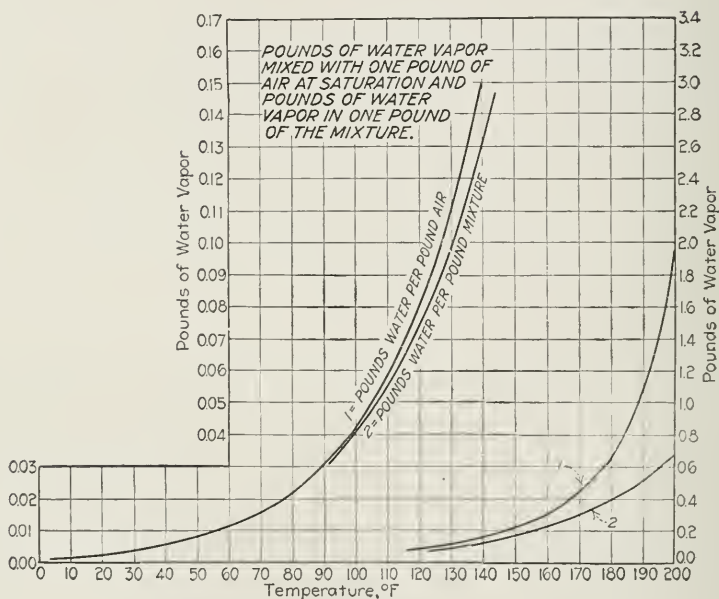


CHART 6.

in this case the air furnishes the requisite heat for the evaporation. As a brisk wind moves a greater quantity of air past the wet surface, it will readily be seen that the evaporation must necessarily be more rapid. The temperature of the wet clothes will depend on the saturation and temperature of the air, but cannot go below the values of Chart 4. Here in a simple illustration are all the fundamental principles of air drying.

The writer has been asked why we cannot take a sufficient quantity of air and dispense with artificial heat. We can, but if it costs more for apparatus and power to move and utilize this air than it would cost to supply the required heat we have gained nothing and perhaps have the additional expense of conditioning or filtering the larger quantity of air.

From the above it will be seen that while air drying at an elevated temperature partakes in some respects of the advantages of vacuum drying, it may not be as economical in the expenditure of heat, inasmuch as heat has to be supplied to raise the temperature of the air, as well as to furnish heat for the evaporation of water (or other fluid).

Having briefly touched on the principles of air drying, let us see under what conditions it may be profitably employed:

1. The drying at relatively low temperature of a substance which is continually entering and leaving the apparatus. In this case it would be practically impossible to obtain a vacuum. An example of this is the drying of pulp, paper, cloth, etc., over hot rolls. Heat is supplied to the rolls and the hot moist sheet leaving the rolls passes through the air and is dried. The rapid evaporation keeps the temperature down to such a limit that the pulp or paper is not seriously affected by the heat. Here continuity of process and nature and amount of the materials are the controlling factors.

2. The drying at low temperatures of substances whose internal structure must be preserved. Examples are, eggs, wood, pulp pipe, etc.,. In the first example, for instance, if eggs were evaporated in a vacuum one would have an edible product, but owing to the rapid evolution of steam from the interior as well as the surface the organic structure would be so destroyed that one could not make an omelet from the resulting product; while if the eggs are air dried by letting this moisture gradually diffuse to the surface the resulting product can be beaten up and a fine omelet can be obtained. The drying of wood in such a manner as to avoid

checking is a more familiar illustration and need not be gone into here.

3. Where the final product must be in a fine state of subdivision and heating even for a short time may destroy some valuable characteristics.

An illustration is the evaporation of milk to milk powder and eggs to egg powder; these substances cannot be kept even momentarily at a high temperature during evaporation without altering or coagulating. Here the milk or eggs are reduced to such fine particles that they are nearly all surface. When these particles come in contact with hot dry air they part rapidly with their water and this rapid evaporation prevents their reaching too high a temperature.

Mr. O. G. Soule of Merrill-Soule has kindly furnished me with the following information as to the evaporation and drying of milk:

The milk is first condensed in a vacuum pan until it contains approximately 33 per cent solids. This is done for two reasons: first, it is a cheaper method of evaporation than evaporation entirely by spraying into the air. Secondly, the resultant product when finally dried has what is called a greater apparent specific gravity, that is, the powder is more compact and in an equal volume will have a greater weight than the product obtained entirely by the air spraying. After evaporation under vacuum to 36 per cent solids, the product is sprayed under pressure of between 3000 and 4000 pounds to the square inch through a minute orifice, with the result that the milk is subdivided into very fine spheres. This product is sprayed into a drying chamber through which is passed a current of air heated to approximately 180° F. The small particles of the liquid are thus entirely suspended in this current of air in the shape of minute spheres, representing an enormous surface and resulting in very rapid evaporation. The product as it dries falls to the bottom of the drying chamber, or is carried along with the current of air and collected outside the drying chamber by means of a dust collector of special design. Since evaporation takes place in the air entirely, the particle being evaporated is kept cool during the evaporation, while if evaporation takes place in contact with a heated metal surface the product during evaporation is itself heated, and the albumin of the milk tends to coagulate. In the Merrill-Soule method of drying, this cooling effect is obtained

and the product does not become heated until the moisture is substantially removed. The advantage of this is apparent from the fact that neither the vitamins nor the enzymes are materially injured by this process, neither is the albumin coagulated. When the milk powder is reconstituted with water they find the original bacteria becoming active, the enzyme action apparently unchanged, and the growth-promoting qualities still in their original form. This, so far as they are aware, is a result unobtainable in any other way. While the milk powder is in its dry state there is found no material action taking place on account of the bacteria therein. The bacteria do not multiply, but rather tend to decrease in the product due to the absence of moisture. On the other hand, when moisture is put back into the powder the bacterial action goes on as in the original milk, and a similar fermentation takes place as takes place in milk.

A similar process is also applied to the drying of eggs; the egg albumin is not coagulated and is soluble in cold water.

As a matter of commercial practice milk is pasteurized before drying, thus killing pathogenic bacteria, and practically the only bacteria left in the powder are of the lactic acid variety, which are of course harmless or useful.

4. Drying such substances as are not affected by heat but are either sticky or poor conductors of heat.

Such for example is the process used in drying salt, lime sludge or the black liquor made by the soda and the so-called sulphate processes for wood-pulp. In the latter case water is not only evaporated but the residue is also charred so that it loses its sticky qualities, but as the object is the recovery of the soda base this does no harm.

DRYING BY MEANS OF RADIANT HEAT

The writer discussed radiant-heat drying at considerable length in a previous paper before this society and so has no need to go into it here; neither is the time at his disposal sufficient to warrant its discussion at this time.

Suffice to say that probably in the near future it will be used in concentrating many substances which require a high temperature for evaporation and where there is no suitable material of which to construct the types of apparatus now in use. It is now used for the evaporation of the so-called sulphate black liquor. It is

thought that this process offers a great opportunity to solve the difficulties encountered in connection with the phosphoric acids.

CHEMICAL DRYING

The ability of certain chemicals to absorb water or other fluids is made use of in drying many substances and the principles are so well known to the chemical engineers that we can dismiss the subject by giving a few illustrations. These fall into a natural classification according as the wet material is a gas, a liquid, or a solid.

1. Undoubtedly the most use is made of this principle in drying gases. Here we have two vapors mixed which it is desired to separate. This mixture of gases is passed through a chemical which absorbs one and allows the other to pass through unchanged. Thus in the hydrogenation of oil dry hydrogen is required. In this case the wet hydrogen is passed through concentrated sulphuric acid, where the moisture is absorbed. Most wet gases attack pipes of the ordinary materials, but if they are dried few if any have any action whatsoever. Chlorine, sulphur dioxide, hydrochloric acid gas, hydrogen, and hydrogen sulphide are examples of gas which are handled in large quantities in this manner.

2. Liquids are sometimes dried in the same manner as gases. An emulsion of oil and water may be separated by hydrochloric acid gas. Mineral oils are dried by the use of sulphuric acid and in cases where a trace of acid must not be left they are dried by the use of calcium carbide. In either case the oil comes out more or less dry. Chloroform is dried over calcium chloride or zinc chloride as well as sulphuric acid.

3. Solids may be dried either by contact with an appropriate gas or by immersing in a volatile liquid which, uniting with the substance to be removed, will pass off easily at a much reduced temperature. As an illustration of the first method, we may take the drying of crystallized magnesium chloride. In ordinary evaporation this would break up into magnesium oxide and hydrochloric acid, but if dry hydrochloric acid gas is passed through it under pressure, the drying will be accomplished and the decomposition largely prevented. Or again, according to the second method, magnesium chloride may be dried to the decomposition point and then mixed with amyl alcohol and the mixture evaporated. In

this case very little decomposition takes place if the amyl alcohol is in sufficient excess and the operation is done in a vacuum.

Again, butter fats may be dissolved from their water and other admixture by dissolving in deodorized rhigolene or cymogene and evaporating the solvent at a low temperature.

MECHANICAL DRYING

This hardly comes within the scope of this paper and will be dismissed by classifying and giving a few illustrations. Five fairly common means might be distinguished:

1. Squeezing;
2. Filtering;
3. Centrifugal force;
4. Heating;
5. Refrigerating.

1. The hydrostatic press may be used to dry wet materials, as for instance in pressing the water from wood-pulp, oils and water from seeds and water from fabrics. The compression of a saturated gas reduces its capacity to hold water vapor at the same temperature, and effects a partial drying.

2. Filtering may be illustrated by the separation of lime sludge from caustic liquor in a filter press.

3. The centrifugal machine in most cases is simply a filter in which centrifugal force is substituted for hydrostatic pressure, though in some cases the centrifugal force is so applied that it merely accelerates the natural separation of two materials of different specific gravities.

As a filter the centrifugal machine is used most in separating crystals from a mother liquor. Thus in separation of salt crystals from caustic solutions or sugar from its mother liquor.

Centrifugals are used in the other manner in separating oil from water, or in separating an emulsion of cottonseed oil, water and soaps of the fatty acids; or in separating the oil emulsions encountered in steam power plants.

4. Air at its dew point may be dried in the physical sense by heating it. This is done in heating ventilation, etc. Of course, chemically there is just as much water in the air after heating as before heating, and this is only a case of apparent drying.

5. Conversely, air may be caused to give up its moisture by refrigerating. This principle is made use of in the dry blast process in the production of iron and steel. Sometimes a gas may form a compound with water or other substance to be removed, and may be used to dry itself. Thus, if liquid chlorine is sprayed through moist chlorine gas or liquid sulphur dioxide through moist sulphur dioxide gas, the liquid will vaporize, abstracting heat from water and gas, and the water will be precipitated in solid form in more or less loose combination with the chlorine or sulphur dioxide, as the case may happen to be.

HEAT CONDUCTIVITY DATA

The subject of evaporation and drying in the sense as used by chemical engineers is indissolubly connected with the subject of condensation and the heat conductivity of the materials used in the construction of apparatus.

The data used for conductivity through the metal partitions which we are interested in when it comes to the designing of an evaporator is not the thermal conductivity of metals as given by physicists, as the conditions are not the same as those under which the physicists obtained their data. For instance, the heat conductivity of copper is given as 500, that of iron 233, and that of lead 103, all in B.T.U. per square foot per inch thickness, per degree F. difference per hour. Now as a matter of fact these data are of very little use if any to the engineer who has the problem of designing an evaporator for a liquid of given properties. If you have an evaporator with iron tubes in which water and steam are the fluids on the two surfaces of the partition you will get a conductivity of from 200 to 250 B.T.U., during the first stages of the heating, but during the second stage, that is, when ebullition becomes rapid, the conductivity increases to 1000. Now the iron has not changed in the slightest degree, but the latter apparent conductivity is from four to five times as great, showing that we must look for some other factor than the conductivity of the metal alone. The factor in this case is the movement of the molecules of water. Water not in motion is a very poor conductor of heat, but when new molecules are brought in contact with the heated surface the absorption of heat from the heated surface is very much increased. Practically speaking, then, the large factor of conductivity in this case is not the metal but the rate at which heat is conducted from the

surface of the metal to the liquid, and this factor may be expressed in terms of velocity of the liquid. The writer has obtained a conductivity of 1200 B.T.U. per square foot per degree F. difference per hour through lead pipe by increasing the velocity of the liquid flowing through it. Under these same conditions, copper tubes did not increase the conductivity more than could be accounted for by experimental error. Iron may have an apparent conductivity of 200 to 250 B.T.U. to water not in motion, but if melted sulphur is substituted for the water the apparent conductivity drops to 3 B.T.U. A familiar case of the above is an ordinary boiler tube, which having air on one side and water on the other, may not conduct more than 3 to 6 B.T.U. per degree difference F. Here again the iron has not changed but the material outside has changed. In this case the determining factor is not velocity but nature of the bounding substances. A horizontal tube with water on the outside and steam on the inside will not have the apparent conductivity if it is 10 ft. long that it has if it is 3 ft. long. Here the determining factor is the length of the tube. As the steam condenses we have an accumulation of water on the bottom of the tube, and the depth of this increases as the length; since water itself is a poor conductor and is not in this case in rapid circulation, it does not transmit heat readily to the tube. In the case of vertical tubes in which the liquor is on the inside there may be varying factors. The diameter may or may not be an influential factor. As you increase the length of the tube you tend to increase the velocity of the fluid inside the tube. This tendency to increase the velocity is due to the increase of the unbalanced pressure between relatively cool bodies of liquor in other parts of the bath and the warmer column of liquid and vapor circulating upward through the tube. This acts in much the same way as increasing the height of a chimney increases the velocity of the hot gases in the chimney. The effect of increased height may be offset, however, by an increase in the diameter of the tube, since in tubes of equal length the surface increases as the diameter, while the volume increases as the square of the diameter. It can readily be seen that the volume is so increased by increasing the diameter that the increase in heating surface is more than counterbalanced by the increase in weight of the liquor to be heated. See Chart 7 and Chart 8. This is what happens in the large central tube in some evaporators or the outside zone in other evaporators, a down-

ward instead of an upward current being maintained. An increase in the height of a tube may not always increase the heat conductivity. If the tube be so small in diameter and its length so great that all the liquor entering it is transformed into steam, then no increase of height will be of benefit but will on the contrary be a detriment.

PHENOMENA IN AN EVAPORATOR TUBE

There is a limit also to the amount of evaporation which can be done in a tube in comparison to the volume of liquor circulating through the tube. Generally speaking, the economical operation of such evaporations is limited to that point where incrustation on the tubes, due to evaporation, commences. It may be asked why this point should arise or why an evaporator should be run in such a way as to approach this limit, when we know that as we approach it we add operating and mechanical difficulties to those which we already have in sufficient abundance. The answer is that unfortunately some liquors have such foaming tendencies that no way has yet been discovered to evaporate them without conducting the operation in such a manner as to make this point of vital importance. As an illustration it might be said that the writer had designed, built and operated evaporators with tubes two inches in diameter and seven feet in height and in which the liquor inside the tube rises only three inches above the bottom tube sheet. These levels of course were measured before steam was turned on and ebullition commenced. Foam, in the sense as used in evaporation, may be considered as a globule of vapor surrounded by a film of liquor. By keeping the level of the liquor low in the tubes the unbalanced pressure on the liquor entering the tube is reduced. The foam formed in the bottom part of the tube rushes up through the hot tube and part of the fluid in the films is evaporated, thus increasing the relative amount of vapor and decreasing the amount of fluid. A point is reached where the volume of vapor is so great as compared with the volume of the remaining liquor that this liquor can no longer stretch as a continuous film about the vapor, and its separation may be accomplished. There is an all-too-common fallacy that increasing the height of the steam dome over a foamy liquor will decrease the foam. It cannot be done in this way, and a little consideration of the principles involved will convince the most skeptical of the fact. If the

height of the liquor in the evaporator is increased, the volume of the bubbles is decreased by the static pressure, according to Boyle's law, which, as the temperature is constant, may be written $PV=C$, where P is the pressure, V is the volume, and C is a constant. Then the volume of the bubbles is inversely proportional to the absolute pressure. If the static head is sufficient, the heat transmitted through the tubes may be absorbed in the liquid at a low zone without the liberation of vapor. As the liquid travels upward the static pressure becomes less, until at a certain point vapor can be liberated; this vapor constantly increases in volume until the surface is reached. It is evident from the above that

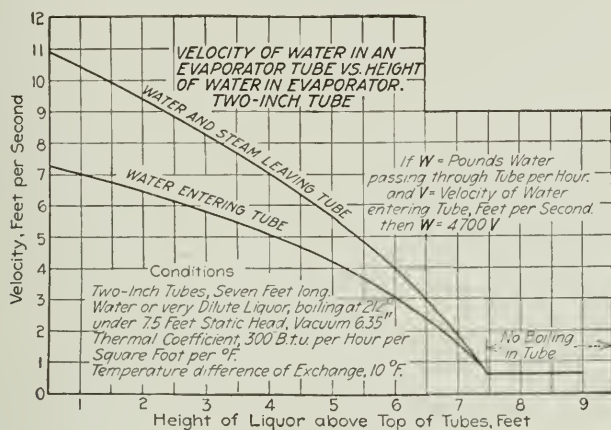


CHART 7.

increasing the height of the dome above the heating surface only changes the zone of the foam, but not its quantity.

The height of the liquor above the tubes may in some cases be a very important and in some cases a controlling factor. For example, let us consider a case in which the liquor reaches a state of saturation for one ingredient long before the desired concentration of another ingredient is obtained. Such an example might be, for instance, the concentration of a solution containing both caustic soda and sodium chloride. Here as evaporation proceeds salt is precipitated, while the caustic soda remains in solution. Now these sharp crystals of salt at a high velocity exert an abrasive action on the tubes.

Chart 7 is submitted principally for the purpose of illustrating

this point. The conditions assumed for the calculations of this chart are: the evaporation of water alone under a vacuum of 6.35 inches mercury, boiling taking place at 212° under 7.5 feet static head, diameter of tubes 2 inches, length of tubes 7 feet, thermal coefficient chosen more or less arbitrarily as 300 B.T.U. per square foot per degree F., average temperature difference of exchange 10° F. No account is taken of the increase in conductivity due to increased velocity.

An examination of this graphic shows that so long as the static head is sufficient to keep the heat in the water instead of forming steam there is no change in the velocity of the liquor in the tube, viz., with a static head above the tubes of 7.5 feet of water the velocity is about .65 foot per second, and this is the same for 8.5 feet static head of water. If, however, there is a static head of only 1 foot, the velocity of liquor entering the tubes is 7 feet per second, and the velocity of the mixture of steam and liquor leaving the tubes 10 feet 4 inches per second. Now let us apply this to the caustic soda illustration, remembering that this chart is only illustrative of water and that the values would be different for caustic soda, but that the underlying principles are the same.

Where heat is transmitted to the caustic but steam is not formed, the salt remains in solution and it is only upon the transformation of the water into steam that the salt is deposited. If this transformation takes place in the tube, the salt is deposited in the tube and at the high velocity shown exerts an abrasive action on the tube, which increases toward the top of the tube, owing to the increased velocity. This velocity may, in some cases, reach the proportions of a continued explosion.

In the other case, where the liquor is not transformed into steam in the tubes, it circulates upward until finally as the static head is reduced to the limiting value steam is liberated above the level of the tubes entirely, and the salt is deposited where there are no tubes to cut out. Now much of this salt can be settled out and what remains travels through the tubes at such a low velocity that it has no cutting action.

The writer has seen many tubes cut off at the top due to the explosive action of steam and salt, while the middle and bottom of the same tubes would show only the slightest wear.

Compare Chart 8 with Chart 7. The only difference in the conditions is that in Chart 8 the tubes are 4 inches in diameter

instead of 2 inches. The effect of decreasing the velocity is apparent and needs no further comment.

The shape or surface of the tube may, in some cases, be the controlling factor. Thus, if a corrugated tube is compared with a smooth tube of the same size and of the same material, it will be found that at low velocities the thermal coefficient of the corrugated tube is greater than that of the smooth tube. At high velocities the reverse is the case. With the corrugated tube the maximum thermal coefficient is reached quickly and at higher velocities may remain constant or even drop. While the writer's data on this point are unfortunately not complete enough to warrant graphical

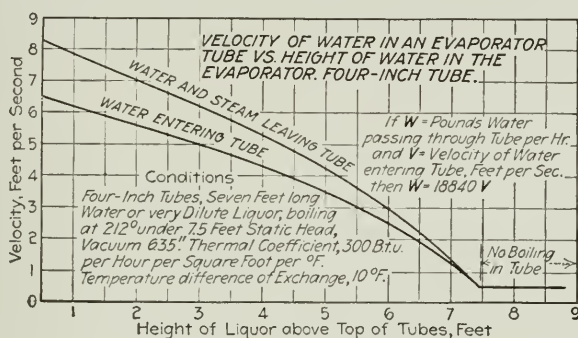


CHART 8.

presentation, he has never yet found such a maximum conductivity in a smooth tube.

CALCULATION OF TEMPERATURE DIFFERENCES

In the design of evaporators one of the necessary factors employed in the calculation is the mean temperature difference. Chart 9 shows graphically the varying conditions one may have. Fig. 1 shows a condition where there is a hot medium imparting heat to a cold medium flowing either direct or counter-current, and yet no change in the temperature of either. In other words, the temperature difference at any point in the flow is equal to the mean difference. An example of such a condition would be found when one had melting ice in contact with one side of a partition and saturated steam on the other side.

Figs. 2 and 3 are examples in which the temperature of the media change, but the temperature difference remains constant. A con-

crete example would be a counter-current exchanger in which the hot liquid entered at 80° and left at 60° and the cold liquid entered at 40° and left at 60° . In all of the above cases it is a very simple matter to get the mean temperature difference. But in the case of Fig. 4, when the cooler medium is at constant temperature and the warmer medium changes in temperature, as in the example of hot water being cooled by ice or a liquid at boiling-point, the mean temperature difference can only be determined in a more complicated manner.

Fig. 5 shows a counter-current conduction example in which the temperature of one medium changes faster than that of the other; such, for instance, as would be the case if the specific heats were different or if the volumes flowing in unit time were different.

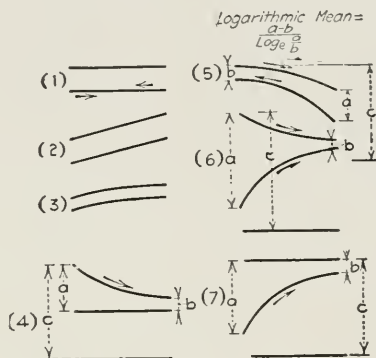


CHART 9.

Fig. 6 applies to a parallel-flow exchanger in which the conditions might be as above with the exception that the fluids flow in the same direction.

Fig. 7 applies to a case in which one fluid changes in temperature by receiving heat from another which does not change in temperature. Such an example would be heating water with steam.

Hausbrand has already developed this subject at some length in his admirable treatise entitled "Evaporation, Condensing, and Cooling Apparatus"; and so it need not be repeated here. Hausbrand has, however, made the subject appear more complex than it really is. Chart 9 is simply Hausbrand's formula simplified. If (a) is the greater temperature difference of exchange and (b)

the lesser temperature difference of exchange, then the true mean difference, commonly called the "logarithmic mean," (Lm), may be found by the formula

$$Lm = \frac{a-b}{\log_e \frac{a}{b}}$$

This formula would, of course, not be used for the simple cases of Figs. 1, 2, and 3, of Chart 9. The logarithmic mean in the other cases may vary from the arithmetical mean by amounts ranging from zero to more than 25 per cent, depending on the ratio of the lesser difference of exchange to the greater difference of exchange.¹

TYPES OF MULTIPLE-EFFECT EVAPORATION

We have mentioned herein in a general way the conditions which more or less determine the type of evaporation which shall be followed in a given case. We have not, however, taken into account the fact that there may be varying conditions in the same type of evaporation. In multiple-effect evaporation, for instance, we may follow two distinct and separate procedures.

They are first, forward-flow, the arrangement in which the liquor and steam enter the first effect and the resulting vapor, condensed steam and stronger liquor go toward the last effect; second, backward-flow or counter-current flow, in which the steam enters the first effect and the resultant vapors and drip flow toward the last effect, while the liquor enters the last effect and is pumped from effect to effect until it emerges concentrated from the first.

In the following illustrative charts the results are only correct to the limit of slide rule accuracy. No allowance has been made for loss of heat by radiation, inasmuch as the amount of this loss can be practically eliminated if one wishes to do so, by putting on a sufficient insulating covering of the right character. The value of the charts will be found in comparison, and as we have several variables to consider, effort is made to illustrate them in order.

¹ Since writing the above, I find in the November number of the *Journal of American Society of Mechanical Engineers*, a very interesting article by Howard M. Ingham on this subject. He shows an ingenious method of finding the logarithmic mean graphically.

FORWARD-FLOW AND BACKWARD-FLOW

OPERATION

Suppose we have a solution weighing 5854 pounds, containing 8.54 per cent, or 500 pounds, of solids which have a specific heat 0.5. The liquor enters the system at 32° and we are allowed 20° difference of temperature exchange in each effect. The problem

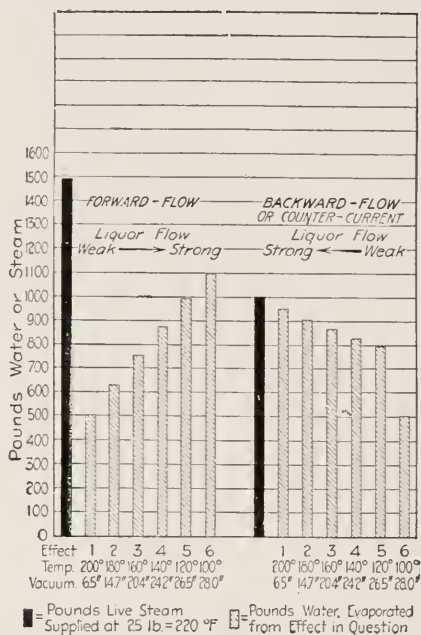


CHART 10.

is to concentrate this weak liquor to a 50 per cent solution in six effects. In order to study, as far as possible, one variable at a time, let us assume in this problem that concentration does not materially raise the boiling-point. Chart 10 shows that to evaporate this liquor, starting at 32° F., by the forward-flow method approximately 1490 pounds of live steam are required from the boiler as against 1000 pounds of live steam required by the backward-flow or counter-current method. The next feature to be noticed is that while by the forward-flow method the evaporation increases as the pressure diminishes from effect to effect, in the

backward or counter-current flow the evaporation diminishes as the pressure diminishes. In either case the temperature and pressures are the same. In the forward-flow method there is the loss of heat in the extra 490 pounds of condensed steam at 120° , equivalent to 43,120 B.T.U., and the loss of heat in the additional 590 pounds of steam at 190° F., equivalent to 651,960 B.T.U., which is lost to the condenser from the last effect. It will be seen that the great loss in heat in the forward-flow is through the condenser;

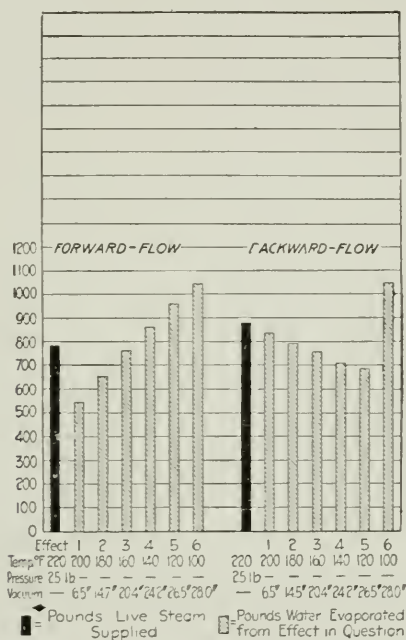


CHART 11.

in backward-flow operation much of this heat is utilized in heating up the liquor. In forward-flow operation the cold liquor, instead of being heated by waste heat, so to speak, is heated by live steam.

In the foregoing problem we have assumed that the liquor enters at 32° F. Chart 11 shows the calculated results of a problem in every way identical with the first, with the exception that the liquor enters at 160° F. instead of 32° F. In this case we find that it is more economical of steam to use forward evaporation. Forward evaporation requires 786 pounds of live steam, while

backward or counter-current evaporation requires 882 pounds of live steam. Here there is a direct economy of steam in the forward method, to say nothing of the elimination of the necessity of pumping the liquor backward from effect to effect. In forward evaporation the amount of steam saved is not only that which would have been necessary to heat the liquor from 32° to 160° , but also the additional saving due to losing less heat in the drip, *i.e.*, as the additional steam required in the other case, after being condensed, carried away a large amount of heat, the saving of this steam also saves this waste. If, however, the evaporation is backward, this heat is lost through the condenser in the steam from the last effect. As we are considering a six-effect system, the

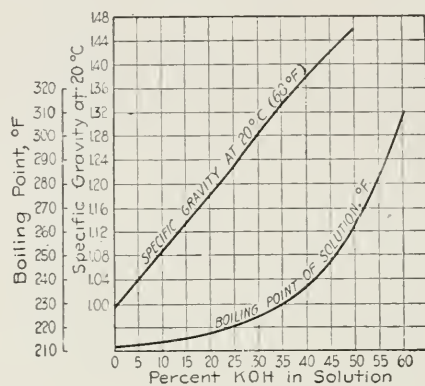


CHART 12.

saving of live steam by forward-flow operation will be roughly one-sixth of the steam lost through the condenser plus the corresponding saving in the drip.

Having now briefly considered a liquor the concentration of which causes no material rise in the boiling-point, let us consider a liquor in which the boiling-point rises markedly on concentration. Chart 12 shows the boiling-points of solutions of caustic potash at different concentrations, and Chart 13 illustrates the evaporation of 5854 pounds of an 8.54 per cent caustic potash solution to a 50 per cent solution. In these calculations the specific heat of the caustic potash is taken as 0.5, as in the preceding problems, not because that is correct, but in order not to introduce another variable. This small error makes no fundamental change in the

chart. It will be seen that in Chart 13 there are all the general characteristics of Chart 10. The input of steam in forward evaporation has increased nearly $25\frac{1}{2}$ per cent, while the input for backward evaporation has increased only $6\frac{1}{2}$ per cent. In forward evaporation the output of steam to the condenser has increased nearly 4.6 per cent, while with backward evaporation it has increased 3.8 per cent. Here, then, there is a large difference in

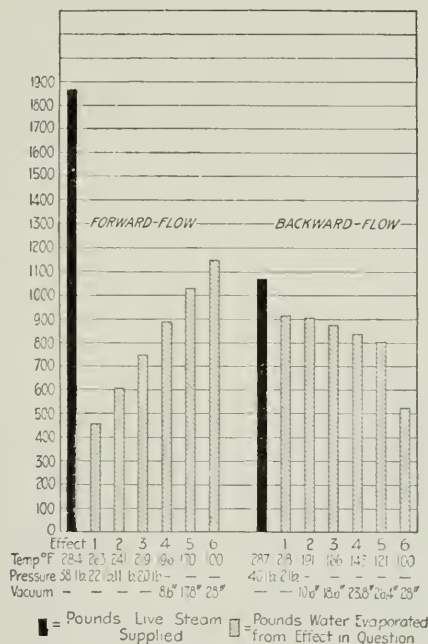


CHART 13.

steam input and very little difference in the steam output to the condenser. It will be readily seen from these charts that this difference is mostly due to the increased temperature of the final condensed steam, and the resultant theft of heat.

TEMPERATURE DIFFERENCES

A study of this chart will also show that the other losses of heat in forward evaporation are greater than in backward evaporation. It is not within the scope of this paper to go into the losses of heat by convection to the air, so I will simply confine

myself to comparisons, with the general statement that the greater the difference of temperature between similar bodies and the surrounding air the greater will be the loss of heat by convection.

The temperature of the live steam space with forward evaporation is 284° , while that of the corresponding space in backward evaporation is 287° , a difference of 3 degrees in favor of the former. The temperature of the liquor spaces are 264° and 267° respectively, still a difference of 3 degrees in favor of the former. The temperatures of the steam domes are 263° and 218° , a difference of 45° in favor of backward evaporation. In the steam spaces of the second effects we have the same temperatures as in the steam dome of the first effects, with a consequent difference of temperature of 45° . Table A embodies these comparisons for the whole six effects. It will be seen from the table that there is a total of 6 degrees in favor of forward evaporation and 750 degrees in favor of backward evaporation, or net 744 degrees in favor of the backward evaporation, an average of more than 40 degrees between corresponding effects.

PRESSURE DIFFERENCES

Now as the temperature controls the pressure, it is perfectly logical to place on the same chart the corresponding pressures. While giving the columns of corresponding pressures, it will be noticed that the column of differences is omitted. The reason is obvious. Whereas a substantial excess of pressure on the liquor over that of the atmosphere may be the determining factor as to whether an evaporator can be run efficiently or not, a difference of vacuum practically makes no difference as far as the mechanical operation is concerned. Thus, suppose we had a solution of caustic potash and potassium chloride; a pressure on the caustic effluent might so fill the discharge nozzles with salt, due to the rapid formation of steam at atmospheric pressure, that the operation would not be feasible because of the danger of accidents.

The successful operation of most evaporators requires the use of one or more peep-hole glasses in order that the attendant may be able to watch for foaming tendencies, etc. Now these sight-glasses, if they are under pressure, may either break or crack, and the liquor may blow out into the operator's eyes; there is also the theoretical possibility of the glass itself blowing into his eyes. If, however, a vacuum is maintained, any such breaking or cracking

of glass will be inwards and the direction of the fluid will be away from the eyes and not toward the eyes.

In the above caustic potash example, owing to the flatness of the boiling-point curve at the lower concentrations, nothing has been said about the heat of chemical combination with water, or heat of dilution, though this factor was considered in making the calculations. The effect is small, however, so that it does not materially affect the elements of the chart. The object sought was to show the results which must follow an increase in the boiling-point during concentration.

TABLE A

Effect.	Com-part-ments.	TEMPERATURE.		Temp. Diff. Favoring Forward.	Temp. Diff. Favoring Backward.	PRESSURES.			
		For-ward.	Back-ward.			Forward.		Backward.	
1	A	284	287	3	.....	38	Pressure	40	Pressure
	B	264	267	3	.....	22	Pressure	2	Pressure
	C	263	218	.....	45	22	Pressure	2	Pressure
2	A	263	218	.....	45	22	Pressure	2	Pressure
	B	243	198	.....	45	11	Pressure	10.6	Vacuum
	C	241	191	.....	50	11	Pressure	10.6	Vacuum
3	A	241	191	.....	50	11	Pressure	10.6	Vacuum
	B	221	171	.....	50	2	Pressure	18.6	Vacuum
	C	219	166	.....	53	2	Pressure	18.6	Vacuum
4	A	219	166	.....	53	2	Pressure	18.6	Vacuum
	B	199	146	.....	53	8.6	Vacuum	23.8	Vacuum
	C	196	143	.....	53	8.6	Vacuum	23.8	Vacuum
5	A	196	143	.....	53	8.6	Vacuum	23.8	Vacuum
	B	176	123	.....	53	17.8	Vacuum	26.4	Vacuum
	C	170	121	.....	49	17.8	Vacuum	26.4	Vacuum
6	A	170	121	.....	49	17.8	Vacuum	26.4	Vacuum
	B	150	101	.....	49	28.0	Vacuum	28.0	Vacuum
	C	100	100	.....	0	28.0	Vacuum	28.0	Vacuum
Totals		.....	.....	6	750				

A = Heating-steam Space.

B = Liquor Space.

C = Evaporated Steam Space.

HEAT OF COMBINATION WITH WATER

Let us now consider the effect of the heat of chemical combination of the solids with water. Unfortunately there does not seem to be any good illustration of a case in which there is not a perceptible change of boiling-point also brought about by dilution. However, if the preceding illustrations are well understood, there should be no difficulty in understanding this variable. One calculation could be made neglecting the heat of chemical combination and another taking this factor into consideration, but the first would be so far from the truth that a comparison of the two results would not only be of no value but would actually be misleading.

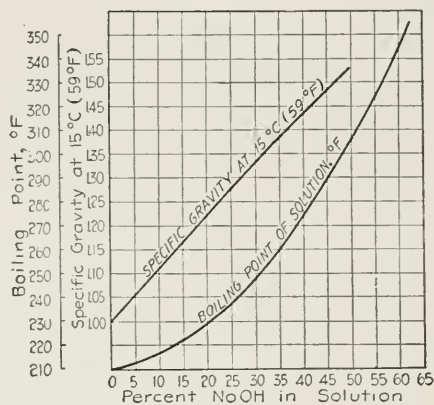


CHART 14.

It is well known that there are many substances which dissolve in water with a marked rise in temperature; such for instance are sulphuric acid, hydrochloric acid, ammonia, and caustic soda. Now it is apparent that if these substances give up heat when added to water, they must likewise absorb heat when separated from water. If this were not so we should have perpetual motion. Now the data obtainable on this subject are not in the form which lends itself to the calculation of evaporator problems. The first thing, then, for one to do who has a problem in which the heat of chemical combination is an important factor, is to take his data and reconstitute them so that they shall be in convenient form. This may be done much in the same manner as a civil engineer makes a contour map from data of elevations and distances. He connects all points

of equal elevations at whatever distances they may happen to be and one is then able to determine the elevation of any particular point by interpolation between successive contours.

Chart 14 gives the relation of boiling-point to concentration of caustic soda solutions and Chart 15 is a "contour map" of the heat of dilution of caustic soda solutions expressed in B.T.U. per pound of water added, concentration being changed between known values. Thus, suppose a 40 per cent caustic solution is to be concentrated to a 50 per cent caustic solution; at the intersection of the ordinate 40 and the abscissa 50 we find that the heat of dilution or vice versa, the "heat of concentration," is 210 B.T.U., for every pound of water so evaporated. Thus, in the heat-balance equation

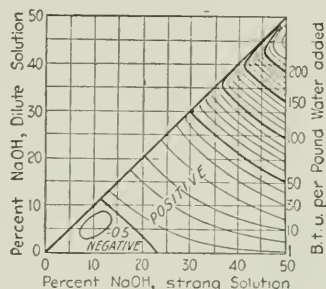


CHART 15.

for one evaporator effect there might be an equation like this, where x is the weight of water evaporated in that effect:

$$\begin{aligned} (1865-x)(161) + 1104x + (5439)(181) + 210x \\ = (1865)(203) + (4259)(224) + 1150x. \end{aligned}$$

It will be seen that after solving this equation for its unknown, the actual amount of "heat of concentration" required may be calculated.

Now in order that we may see the effects of heat of chemical combination and rise in boiling-temperature combined, let us examine Chart 16. The forward-flow operation is an impossible case as far as practice is concerned, on account of the high pressures we have to contend with. This chart shows the conditions encountered in evaporating an 8.54 per cent caustic soda solution at an original temperature of 160° F., to a 50 per cent solution. It will be seen that in effect No. 2 backward-flow operation, the liberation of

steam is greater than in effect No. 1. Heretofore we have had no such abrupt changes. Let us see how this happens. In effect No. 1 there is a high heat of chemical combination, all of which heat is furnished by the latent heat of the live steam, and consequently the steam liberated will be very much less than it would be if there were only a low heat of chemical combination. In the second effect, however, there is a large quantity of condensed steam

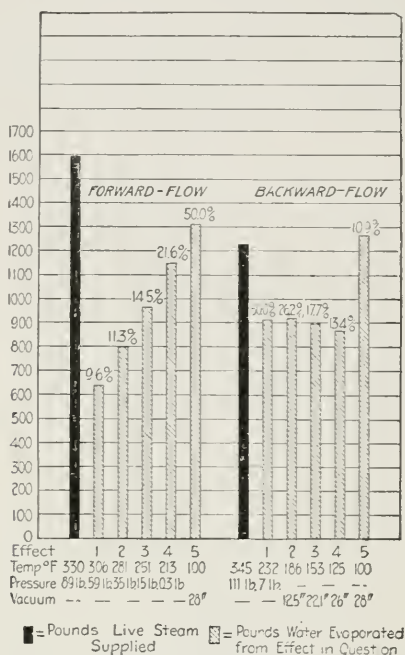


CHART 16.

from the first, cooling approximately 93° . This liberates heat enough to raise the evaporation of steam in that effect above the abnormally low value of the first effect. Referring to Chart 15, it will be seen that the heat of combination between 26.1 per cent and 50 per cent concentration is 109 B.T.U. per pound of water evaporated. This same condition applies to forward-flow, but is not so noticeable (see Effect 5), first, because of the large increase in evaporation from effect to effect, second, because the concentration is in that case between the values 21.6 per cent and 50 per cent, instead of between 26.1 per cent and 50 per cent. If, however,

the differences are subtracted and the results compared with the preceding charts, the effect of this property will be apparent.

In Chart 11 it was demonstrated that the forward-flow method was more economical of steam when the liquor to be evaporated had been preheated to a considerable extent, viz., 160° , in this illustration. But it does not follow that because this is true of liquids in which concentration does not materially raise the boiling-point that it is true for those liquids which increase markedly in boiling point on concentration. Thus, Chart 16 shows that backward-

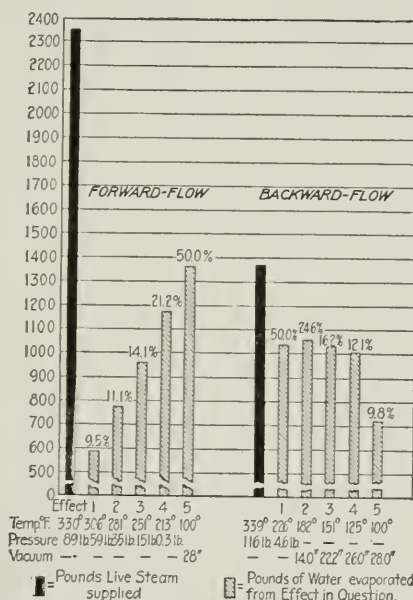


CHART 17.

flow evaporation is decidedly more economical in steam than the forward method for caustic soda. Here it will be seen that the loss of heat in the drip, due to its high temperature, more than offsets the extra heat lost through the condenser in backward-flow.

Chart 17 is submitted showing the evaporation of the same caustic soda liquor with the conditions the same except than the liquor enters at 32° . Here the same rise in evaporation in No. 2 effect backward-flow is apparent, and the decrease in evaporation of No. 5 effect in forward evaporation is equally apparent; as

before, the abnormalities are due to the large heat of chemical combination at these points.

In the two last charts the effect of the heat of chemical combination has been illustrated, using a caustic soda solution as an example. In this case the heats of chemical combination are positive. It might be interesting to take an example such as the concentration of ammonium nitrate, in which the heats of dilution with water are negative. The time at the writer's disposal does not permit of his making the necessary charts or calculations, however, and moreover, we have already considered the subject of heat of chemical combination as fully as is justifiable in a general paper.

USEFULNESS OF THE CHARTS

A study of the charts already submitted will show that not only do they give an idea of the consumption of steam and the mechanical strength required, but that by calculating a chart for the problem in hand one can save in first cost of equipment. For instance, in Chart 16, the condenser for backward-flow operation could not be much smaller than in forward-flow, though the boiler might be smaller. This chart also shows that the piping into the condenser in each case would be about the same size. Also, inasmuch as the amount of steam to be condensed is very nearly the same, the amount of water to be handled is much the same.

Comparing the two divisions of Chart 17, one will see that the boiler has to be approximately 70 per cent larger for forward evaporation than for backward evaporation. The condenser in the former has to possess 90 per cent greater capacity than in the latter, and the water supply and equipment must also be greater. The question of water supply alone might decide one in favor of the backward-flow type of evaporation.

Another fact to be observed is that in the backward-flow process the intermediate piping can, as a rule, be approximately of uniform size without waste, while such is not true of the forward-flow method. The former method lends itself better to standardization.

A further study of the subject will show that in the forward-flow method, to a much greater degree than in the backward-flow method, adding an additional effect does not give a proportionate economy of evaporation, and that interest on the investment and maintenance charges may more than offset the economy gained.

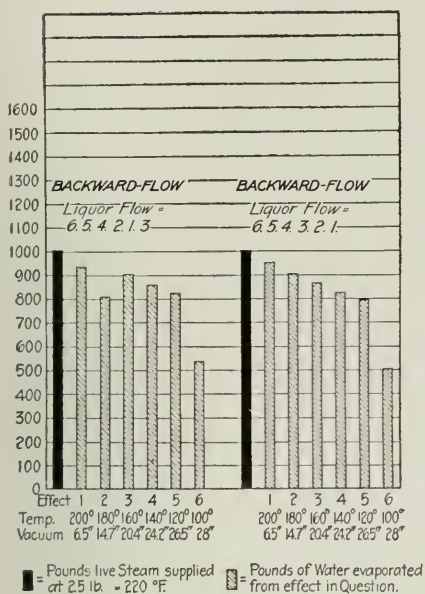


CHART 18.

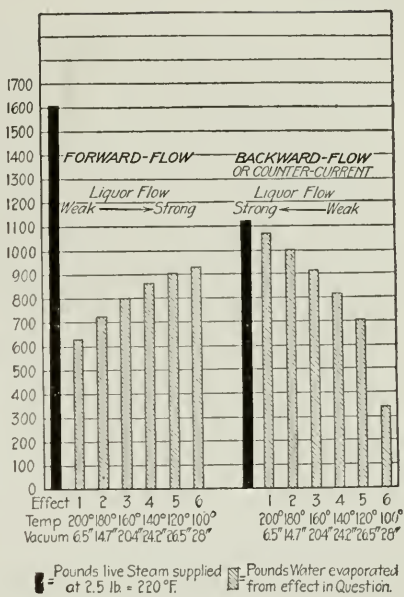


CHART 19.

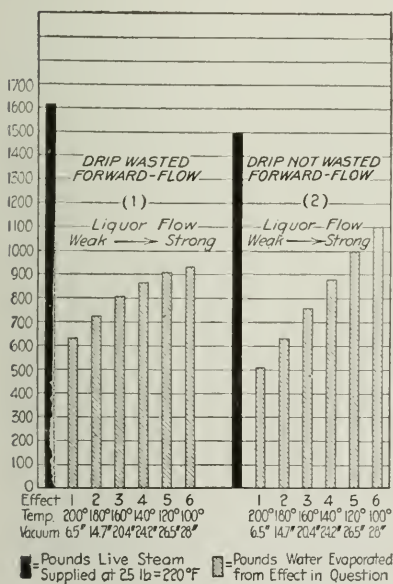


CHART 20.

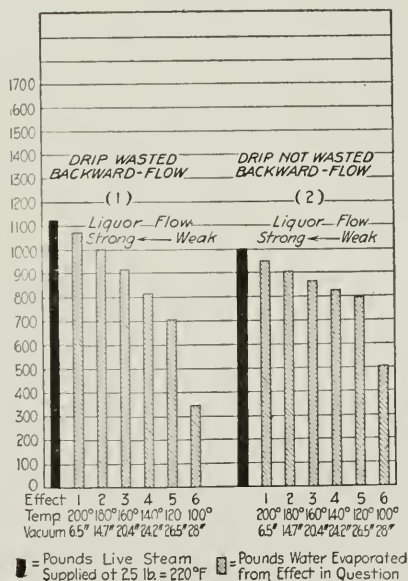


CHART 21.

TEMPERATURE DIFFERENCE OF EXCHANGE

In the foregoing illustrations the temperature difference of 20° F. has been used in each instance. This has been done in order that the point which we wish to consider shall not be obscured by greater variations. It is not, however, meant to intimate that evaporation is always done under 20° difference of exchange, or that 20° is preferable to 10° or 25° . The writer is familiar with an evaporator in which the following are the approximate differences of exchange: 8° , 9° , 15° , 20° , 26° , and 70° . This is due to the increase in viscosity of the liquor.

Where a liquor tends to decompose or "gum up" on concentration at high temperatures, and becomes viscous at low temperatures, there is still another procedure which can be followed. Suppose the travel of the liquor is as follows, the effects being numbered serially: 6, 5, 4, 2, 1, 3. Here the liquor gives up its last water at a temperature high enough so that it will remain mobile. A large number of these combinations might be made, and the subject is of enough importance to warrant investigations along this line. The experimental data available at present are not sufficient to warrant submitting calculations. We have, however, gone far enough in certain experiments to lead us to believe that in spite of the extra complications this method will be useful where conditions are unusual.

As the thermal coefficient increases with the velocity of the liquor (and therefore also with its mobility) it will be readily seen that by increasing the velocity (or mobility) of the liquor the heating surface required can be reduced.

The velocity or mobility of the liquor is not, however, the only thing to be considered in designing the heating surface of multiple effect evaporators. If air accumulates in the steam space, the effect is the same as reducing the heating surface. It has been assumed for lack of better knowledge on the subject that this effect is in direct proportion to the per cent by volume of air present and the evaporator designer will not go very far wrong if he goes by this rule. The accumulations of air in only one effect may stop the operation of every evaporator in a multiple-effect system. It will thus be seen that evaporators should be so designed that the inlet and outlet for air and its accompanying steam will be so located as to prevent air pockets.

DRIP FROM EVAPORATORS

Many manufacturers waste the condensed steam, that is, they remove the "drip" of each effect separately, and do not try to obtain the available heat therein. This in some cases is justified, though as a general practice the principle is unsound. A justifiable use is in the case of foamy materials where the liquor may be expected to foam over without warning. In this case, if the drips are kept separate, only a portion of the drip liquor would have to be re-evaporated in case of accident, instead of the whole. The efficiency, however, is not as great as when the drip is carried from one effect to another. If the saving due to less re-evaporation is greater than the saving in steam the method is justifiable. A chart might have been drawn to illustrate this, but lack of time has prevented.

Multiple-effect evaporators should be connected with by-pass valves, so that any effect may be repaired while the others are running.

In conclusion, the writer wishes to express his hope that this paper may suggest subjects for a full discussion, by which means he is sure matters of the greatest interest and profit to the Society may be brought out. He also wishes to acknowledge valued assistance rendered by Mr. W. B. Van Arsdel in the preparation of the material presented.

For discussion of this paper see page 420.

BERLIN MILLS Co.,
Berlin, N. H.

SOME PROBLEMS IN EVAPORATION AND DRYING

By **P. B. SADTLER** and **F. M. de BEERS**

Read at the St. Louis Meeting, Dec. 7, 1917

In our work of designing and building evaporators for all kinds of service, we are often presented with new operating conditions, new results desired and new chemical engineering problems that are extremely interesting. While we recognize the necessity and importance of a thorough training and knowledge of the theoretical side of this business, we have also been shown that the important thing, so far as the satisfaction of our clients and the advancement of the chemical industry are concerned, is the practical application of these theories usually based upon some previous experience that we have analyzed as far as possible on the basis of these theories. It often happens that a process will be worked out in a laboratory and the evaporation part of the process will appear to be very definite as regards certain important features, but our analysis of the result will introduce factors that never appeared at all in the laboratory. For example, we had a client who wanted to concentrate a certain solution beyond the saturation point of the salt contained in the same, with the intention of precipitating that salt in the evaporator. The solution was concentrated on a fairly large scale in the laboratory, and the crystals were perfect in form and rather large, somewhat larger than dairy salt, for example. Our analysis of the problem from a rather practical standpoint lead us to believe that, under actual operating conditions on a large scale, the crystals formed would be very small. This was not because all crystals formed in the particular type of evaporator we intended to use are small, as in most cases the crystals are well formed and of a size much larger than we said would be the case with our customer's product. Our reasons for saying the crystals would be small were as follows: The solution itself and the mother liquor, as the crystallization began, were both easy-boiling solu-

tions, practically as fluid as water, with no viscosity, and very few impurities present. The specific gravity, while high, did not give a liquor having the physical qualities of sugar solutions, caustic soda, etc. The salt formed was very heavy. The circulation in the type of equipment used is very rapid. We reasoned that there would be no chance for the crystal to build up, because of the rapid circulation and the molecular weight of the salt formed. The circulation would remove it from the heating or concentrating zone quickly. The solution being very fluid would not tend to keep the crystals in suspension and the tendency to quickly settle out was, of course, assisted by the high molecular weight of the salt itself. In this way the small crystals would separate from the solution circulating through the tubes and there would be no chance of their becoming larger. With a viscous solution and where the salt formed is not very heavy, the crystals stay in suspension until they are large enough to overcome these factors, when they settle out, notwithstanding the rapid circulation. While they are still small, they remain in suspension and are carried through the heating tube repeatedly and build up because of evaporation produced, and become larger with each passage through the tubes. Until they are large enough to overcome the effect of viscosity and circulation, when they settle out of the path of circulation. This is the case where sodium chloride crystallizes out of a caustic soda solution, or from a glycerine solution. Referring back to the problem of our clients, we reasoned that the crystal first formed would not be circulated again, and consequently would be small, and we designed our equipment accordingly. Almost any form of salt separator can be used where the crystals are large, but with very small crystals many of the more efficient types of separators or filters have to be discarded. The filters we put in were not as efficient as other types we make, which are suitable for large crystals, but we believed they were the only style to use if small crystals resulted. Fortunately for us our conclusions were correct, as the crystals were exceptionally small—nearly as fine as talcum powder, and if we had followed the laboratory data alone, and used a filter suitable for large crystals, our client would have had no end of trouble, and he probably would have condemned the entire evaporating apparatus.

This is simply an illustration of the value of applying scientific data to any design of evaporator, and the necessity of occasionally

disregarding a more efficient type of construction in order to have an equipment that will be commercially satisfactory.

We often have to advise against the use of multiple-effect economy, or to limit the number of effects because of certain physical properties of the solution being concentrated or because of the chemical characteristics of materials in solution or suspension. We know, for example, that a certain minimum effective temperature difference is necessary for efficient operation. The capacity in pounds of water evaporated per square foot per hour is directly proportional to this effective temperature difference, which is the difference between the temperature of the vapor or steam being condensed and the temperature of the vapor formed from the liquid being concentrated—minus the excess boiling temperature of the solution. The capacity is also proportional to the velocity of the vapor on one side of the tube and to the velocity of the solution on the other side. In most types of evaporators the velocity of the solution is caused by the heating or evaporating of same and the greater the temperature difference the greater the velocity of the solution. In this way the capacity of a tube is greatly reduced, as the temperature difference goes down and the first cost of the evaporator becomes prohibitive, notwithstanding the apparent saving in steam because of the greater number of effects. As the temperature difference and velocity of circulation are reduced, there may be an opportunity for materials to come out of suspension or solution and deposit on the tube which would not form there if the circulation were better. Any solution that has a tendency to foam will give less trouble with a greater temperature difference per effect, and this may limit the number of effects we can use although we have found a way to overcome this trouble to a large extent by following a certain scheme of operation. Where a solution has a boiling-point above that of water we must have an effective temperature difference above this excess or we will not do any work. This matter of excess boiling temperature often limits the number of effects we can economically use from a commercial standpoint.

It is evident, therefore, that any recommendations we make as to type, number of effects, auxiliaries, etc., must be first based on a complete knowledge of the chemical and physical properties of the solution to be concentrated. We must have the complete confidence of our client, otherwise our work can only be half done.

We also believe in explaining our own reasons for every step in the development of the final design which include reasons based entirely on practical experience with some similar material. I would like to explain in detail some of the problems we have worked out, but in all fairness to our clients, I do not feel privileged to refer to specific problems. The results of our work in every case belong to our client and no one but that client should know what he is doing. While we have a large amount of practical data and while there are a few excellent books on the theoretical side of evaporator design, we have often wanted some conclusive evidence in connection with the determination of certain constants and variables that does not seem to be available anywhere. With this in mind we started to look around for a theoretical man who was sufficiently practical to recognize the necessity of making every evaporator profitable from the investor's standpoint. We believe we have located the man, and fortunately he is a professor of Chemical Engineering at one of our large Universities, and it has been possible for us to retain him as a consultant. We then decided to see if a dream of ours could be worked out and approached the University on the subject of a complete industrial laboratory devoted to the securing of definite data relating to the evaporator industry.

I am pleased to take this opportunity of announcing that an arrangement has been made between our company and the University of Michigan, whereby we are giving such a laboratory to the University who will co-operate with us in securing fundamental scientific data relating to evaporators. Dean Cooley and Prof. Badger, as well as the President of the University and the Board of Regents, have co-operated with us to the fullest extent, and within a short time we expect to have some of these factors definitely determined which we now base entirely on practical experience backed by scientific reasoning. All data obtained that is of interest to the scientific world in general will, of course, be published. The establishment of this laboratory should be most valuable to the students in Chemical Engineering as the first purpose of same is for the benefit of the students and our own work will only be done when the laboratory is not needed for student work.

The laboratory is located in the southeast corner of the campus. It occupies half of the building, the evaporators themselves being erected in a room, 64 by 34 ft. The truss roof rises 37 ft. above

the ground floor, which in turn is 15 ft. below the outside ground level. A space approximately equal to the above is available for extra tanks, storage of spare parts, etc. The remainder of the space assigned the laboratory is taken up by an office, drafting room and lecture and class room. Altogether the total floor space approximates 6000 sq. ft.

The evaporator room is traversed by a 10-in., 5-lb. low-pressure steam line and a 6-in., 90-lb. high-pressure main. A 4-in. hot water and a 3-in. cold water line are available. It is also furnished with 220 alternating and direct current and a small air compressor delivering 4 cu. ft. per hour, under a pressure of 25 lb. for mixing liquids, air jet lift, etc.

The installation consists of a 30-in. inside diameter, patented basket type vertical tube evaporator, having a maximum evaporator capacity of 600 gal. per hour; a standard Swenson horizontal tube evaporator (Junior size), a Swenson type "K" machine (semi-film type), and a Swenson patented, high concentrating evaporator. The condensers of all evaporators are connected to an 8 by 10 by 12 in. American Marsh Vacuum Pump, with valves so arranged that the water from one or all condensers can be handled separately.

The entire laboratory has been arranged to give as great flexibility as possible with an eye to future enlargement, and at the same time to enable one operator to care for and control one machine. To carry out this idea a panel is situated on the working platform beside each evaporator, on which are fixed manometers, thermometers, Bristol temperature recorder, etc. Liquid, wash water, drip and thick juice lines all enter on the same side, so that by extension valve stems they may be controlled from the working platform. Numerous taps are provided from which varied size pipes can be run as desired and a $\frac{1}{2}$ -in. screwed gland can be inserted at various points to get pressures of liquid steam, etc. It is intended to use as much as possible, platinum resistance thermometers and pressure and vacuum will be recorded by mercury manometers.

The machines are so constructed that whole sections may be added or subtracted at will. Tube diameters, tube lengths, tube spacing, boiling areas, downtake areas, tube lengths, etc., may be changed without dismantling the equipment. Various types of bottoms for purposes hereinafter described are provided for each evaporator. These are fitted with roller brackets so that they can easily be unbolted, rolled to the edge of the working platform and

handled by trolley to any part of the laboratory. The trolley is also routed to carry any other parts necessary.

For salt depositing solutions a salt filter is mounted on a truck moving on tracks immediately below all evaporators, allowing it to be connected to any one desired. A volute pump is similarly mounted to enforce circulation on viscous and heavy liquids. An interchangeable foam catcher whose efficiency is measurable by a sight glass is part of the equipment.

The laboratory is supplied with a 7-ft. diameter 10-ft. high wood tank to store liquids coming in, and two 8-ft. diameter, 4-ft. high, wrought iron tanks, to be used as mixing tanks and also for storage of the thick liquor. One drip receiver 30 in. diameter and 4 ft. high and one thin liquor weight tank, 3 ft. diameter and $4\frac{1}{2}$ ft. high permanently fixed to a platform scale are provided for each unit. Both receivers and tanks are connected up in series, so that all may be used on one evaporator. They are also calibrated by volume to check results and in addition, measurement of drip water is provided by piston meters.

Thick liquor is measured in a portable weigh tank on a platform scale truck, running on the same track as the filter above described. It is so arranged that it can be exhausted into the large thick liquor tanks by a 5 by 3 by 8 magma pump which is also used when the operation is continuous. These larger tanks are in turn connected in series to the thin liquor tanks on the upper platform, so that a mixture may be pumped from them directly to the evaporator feed line.

Loss due to radiation which is apt to be more or less great on a small machine is to be measured as follows: Shutting off the condenser, a certain fixed pressure should be maintained were it not for the condensation of vapor due to heat losses through the evaporator walls. The steam consumption necessary to maintain the fixed pressure is then a direct measurement of the heat lost through radiation. It is intended to compare results obtained on a large scale test to results in one of our commercial installations, thus having two checks on our figures.

In conclusion it might be said that there is plenty of room for the addition of other chemical machinery which undoubtedly will be added from time to time. Eventually the laboratory will be enabled to handle tests even involving tank cars of liquor. An idea of the height and size of the machines may be given by stating

that including the filter, the vertical tube machine stands 30 ft. tall and will require three working platforms $7\frac{1}{2}$ ft. apart to operate it.

This laboratory will be used to work out Government problems, also commercial problems of responsible individuals or companies. The main purpose of the plant from our standpoint, however, is to give us a place where we have all the equipment and facilities for the determination of evaporation factors with all variables eliminated except the one we are working on. We wish to corrolate theoretical and practical data and do not intend to repeat the work done by such eminent authorities as Dr. Hausbrand, for example. We intend to use to the fullest extent the results of his work and may later check up certain things, largely to gain the knowledge that is only possible through such experiments. Our equipment is large enough to carry on our experiments on a commercial scale with the personal error factor very largely eliminated because of the quantities handled. We want our results to be commercially valuable and among the things we are going to do are the following:

Determination of velocities of steam, vapor, and liquor in various standard type of evaporators and under various normal operating conditions.

Value of catch-alls of various types.

Amount of loss of liquor by entrainment and by foaming and best means of overcoming same.

Separation of crystals from mother liquor.

Location of non-condensable gases and amount of same from various commercial solutions, also source of same and best means for their removal. Determination of loss of vapor with efficient removal of these gases. Determination of volume removed at various stages of the work in a multiple effect, etc.

Conductivity factors in heaters and surface condensers under varying conditions as to velocity, viscosity, size, and shape of tube, etc.

Constants based on work done per square foot of heating surface with the following variables:

Effect of velocity of steam or vapor;
velocity of liquor;
temperature difference;

Effect of vapor density;
crystallization;
scale on tubes;
temperature of entering liquor;
materials in suspension;
materials in solution;
excess boiling temperature;
viscosity;
evaporate type;
density of liquor;
tube length and diameter;
tube depth in a horizontal tube machine;
downtake area and location of same;
metal used for heating surface;
surface of tube on capacity;
protective coverings;
moisture in steam;
hydrostatic head;
area of liberating surface.

Liquor level regulators and their usefulness.

Determination of effect of heat of solution, when concentrating a salt solution.

Best method of regulating size of crystal formed.

These are only some of the things we have planned to do, but this may give you an idea of how the laboratory will be used. We feel we just about know a lot of these things, but want this conclusive confirmation or correction of our own theories which are now largely substantiated by actual results. We would be very pleased to receive suggestions from members of the Institute as to data that should be obtained as regards general or specific evaporation problems. We expect later to expand the laboratory so it will include drying machinery, filtering and pressing equipment, etc. While we are called upon to work out a good many chemical engineering problems that do not relate to our evaporators, the purpose of this laboratory for the present, at least, is simply to secure evaporation data during such time as it is not needed for student work.

For discussion of this paper see page 420.

DRYING CHESTNUT EXTRACT BY THE CARDEM PROCESS

By HARRY McCORMACK

Read at the St. Louis Meeting, Dec. 7, 1917

The paper I have to present is really not a paper—merely a talk along the line of certain tests I conducted on drying chestnut wood extracts by the Cardem Process. I regret very much that I was unable to be present to hear the paper of Mr. Soule, on his method of evaporation, because he is really the pioneer in this line of evaporation and drying, which I am to discuss only in rather limited detail to-day. The Cardem Process of Evaporation is similar to the one used by Mr. Soule in his evaporation of milk. That is, heated air is passed into a chamber into which is atomized the liquor to be concentrated and dried. In the particular plant which I am mentioning to-day, the heat used in the evaporation chamber is obtained by burning coal in a coal-fired furnace, and passing the gases of combustion counter current to the air, which is drawn in through a fan and then discharged into the drying chamber. The drying chamber itself consists of two compartments or floors. In the upper floor the dry powder is deposited and in the floor below this, known as the wet chamber, the dry powder carried in the air currents from the upper chamber is absorbed in water or weak liquor. This weak liquor is pumped back into the pipe lines supplying liquor to the sprays in the wet chamber.

The fundamentals of such a drying operation we find are in the circulation of the liquor into the chamber and the distribution of the heated air going into the chamber. The particular problem connected with such an evaporation is getting an efficient mixture of heated air and liquor to be evaporated. This is accomplished by the means used to deliver the air into the chamber and by the type of atomizer to spray the liquor into the chamber. The particular atomizer used in this plant has a broad $\frac{3}{16}$ -inch opening through which the liquor is sprayed. Back of the disk through which the liquor is sprayed is an initial cut into peculiar form, which gives a spiral flow to the liquid from the pump and to the atomizer. The liquor thus is forced through the atomizer not in a line hori-

zontal to the atomizer opening, but almost tangential to the atomizer opening. This, we find, separates the liquor into a larger volume as it goes into the chamber. The problem which Mr. Soule solved in evaporation of milk to get a dry milk powder differs quite a little from handling such a product as tannin extract. The milk powder is a high-priced article. Mr. Soule can afford in this evaporation to lose some of the very fine powder by its being carried with the air currents passing through it, but we can't afford to lose much chestnut extract in this way, or we will bring our cost of drying to such a point that it is too much of a charge against the selling price of the finished product. The figures I have to give you to-day are taken from some tests which were conducted on this drying plant, the combustion gases from the furnace to the heating chambers being at an average temperature of 525° F.

The Cardem Process of evaporation is a process in which water is evaporated by being atomized into a chamber along with a current of heated air. This chamber is arranged to be insulated as well as possible and to secure as intimate a mixture as possible of the finely divided spray and the heated air. Sufficient space is also provided so that the air currents may lose in velocity until the dried material formed in the process will settle out from the current.

The heated air passes from this chamber in which the dry powder is to settle out into another chamber located beneath the dry chamber. In this lower chamber a number of spray nozzles are located which are spraying dilute extract into the air passing through this chamber. The dilute liquor is contained in the base of this wet chamber and is kept in constant circulation by two centrifugal pumps drawing it from the base of the chamber and forcing it through the spray nozzles.

The heated air is derived from a furnace arranged with sets of boiler tubes, the air going to the drying chamber passing through these boiler tubes, while the hot gases from a coal fired furnace circulate around the tubes.

Measurements were taken during this test of the quantity of coal burned, the quantity of air passing through the several parts of the drying chambers, the quantity of combustion gases being discharged from the furnace together with the temperatures of the heated air and the combustion gases.

The coal burned was sampled and its analysis for moisture, ash sulphur and B. T. U. is used in calculating the various efficiencies.

Samples of extract used in the two tests and originating in different parts of the system were taken. The specific gravity and per cent solids were determined in these samples and from these determinations was calculated the amount of water evaporated and the quantity of dry powder which should be produced.

HOT AIR GENERATOR

Coal for generating the hot air was fired through a Jones Under-Feed Stoker using forced drafts in a closed ash pit and an induced draft fan to carry the gases of combustion from the furnaces and discharge them to the atmosphere.

FORCED DRAFT FAN

This is a number 25 I. L. G. fan, inlet diameter 14 inches, outlet $9\frac{3}{4}$ by 14 inches. Direct connected to a 3-phase A. C. motor. Speed about 760 R. P. M. the inlet to the fan is 12 inches.

Air pressure maintained in the ash pit during the test averaged 2.3 inches static head in water. The temperature of the air entering the fan averaged 87° .

INDUCED DRAFT FAN

This is a number $5\frac{1}{2}$ Bayley Plexiform fan. Inlet $27\frac{3}{4}$ inches circular, outlet $24\frac{3}{4}$ inches by $19\frac{3}{4}$ inches giving a rectangular space of 3.12 square feet. Speed of the fan on this is 630 R. P. M. It is belt driven by a 10 h.p. 3-phase A. C. motor.

Pitot tube readings with a differential draft gauge indicating average velocity pressures were taken covering the area of discharge from this fan. Two hundred and ninety-three readings were taken at one time giving an average differential pressure of .2084. One hundred and eighty-two readings were taken on another test giving an average differential of .205. The figure .205 is the one used in making the calculations contained in this report.

COMBUSTION GASES

The average temperature of the combustion gases was 525.7° F.

The average Pitot tube differential gauge reading was .205.

The area of discharge of the combustion gases 3.12 square feet.

The velocity of air in the discharge is then 1096.4 by the square root of .205 divided by $.04033 = 2471$ feet per minute.

.04033 is the weight of 1 cubic foot of air at the temperature of 525.7° F.

Area of discharge is $3.12 \times 2471 = 7711$ cubic feet of combustion gases discharged per minute.

7711 multiplied by .04033 gives 311 pounds of combustion gases per minute.

The mean specific heat of air between the temperature of 84° F. and 525.7° F. is .2926 B. T. U. per pound.

Then the total heat carried away by the discharged gases of combustion will be $311 \times .2926 \times 441.7 = 40,194$ B. T. U. per minute, or 2,411,640 B. T. U. per hour.

COAL

Coal consumed during the test 3812 pounds.

Duration of test six hours.

Coal consumed per hour 635.3 pounds.

A sample of this coal was analyzed and the results were as follows:

Moisture.....	2.91
Ash dry basis.....	13.30
Sulphur dry basis.....	2.60
B. T. U. dry basis.....	12.355

In each 100 pounds of coal as fired there are 2.91 pounds of water and in 635.3 pounds there are $2.91 \times 6.353 = 17.487$ pounds of water, which must be raised from the temperature at which it is fired, 84° to 212° F., evaporated from and at that temperature and superheated to the temperature of the escaping gases.

To raise the temperature of 1 pound of water from 84° F. to 212° F. will require 128.5 B. T. U.

To evaporate 1 pound of water into steam at 212° F. will require 970.4 B. T. U. and to superheat 1 pound of steam from 212° F. to 525.7° F. will require $525.7 - 212 = 313.7 \times 46 = 144.3$ B. T. U.

We then have $(128.4 + 970.4 + 144.3) \times 17.487 = 21,739.8$ B. T. U. required to vaporize and superheat the water fired with the coal.

B. T. U. coal as fired equals $\frac{12.355 \times (100 - 2.91)}{100} = 12.005$ per pound $635.3 \times 12.005 = 7,627,100$ gross B. T. U. per hour.

$7,627,100 - 21,739.8 = 7,605,360$ net B. T. U. per hour.

FAN HANDLING HEATED AIR

This is a number 10 Bayley Plexiform fan. Inlet diameter 50.3 inches, outlet 41 inches by $35\frac{1}{2}$ inches= $101\frac{2}{10}$ square feet. Speed 500 R. P. M. Belt driven by 50 h.p. 3-phase A. C. motor.

Pitot tube readings were taken to determine the average velocity of the air passing through the discharge duct to this fan. Three hundred and forty-one readings were taken giving an average reading on the differential gauge of .1361. These readings were taken with the writer's portable Pitot tube. Connection was then made with the permanent tube as installed in this air duct, the average differential reading was found to be .175. From this the correct factor for the differential gauge reading was calculated to be .7777.

The correct differential gauge reading during the test was 0.100 inch of water.

The average temperature of the hot air passing through the duct was 455° F.

The weight of 1 cubic foot of air at this temperature is .0434.

From the above figures we calculate an air velocity of 1664 feet per minute.

The area of the duct is 10.24 square feet.

10.24×1664 gives 17,205 cubic feet of air per minute.

17,205 multiplied by .434 gives 746.7 pounds of air per minute.

The specific heat of the air at 455° F. is .2984 B. T. U. per pound.

$.2984 \times 746.7 \times 455$ gives 101,400 B. T. U. per minute being carried by the hot air into the drying chamber.

The temperature drop in the system can be from the temperature of the entering air down to atmospheric temperature.

On the day of test this was from 455 down to 75°, or 380° drop.

We would then have an effective B. T. U. per minute of 84,685.

The air leaving the dry chamber and going to the wet chamber has a temperature of 230° F.

The drop in temperature in the dry chamber is therefore from 455° F. to 230°= 225° F.

The mean specific heat between these temperatures is .2922 B. T. U. per pound.

The heat used in the dry chamber is therefore $.2922 \times 225 \times 746.7$ equivalent to 49,090 B. T. U. per minute utilized in the dry chamber.

The temperature drop from the wet chamber to the air is from

230° F. to 143° F. or 87°. The mean specific heat of air between these temperatures is .2894 B. T. U. per pound.

The quantity of heat utilized in the wet chamber is therefore $.2894 \times 87 \times 746.7 = 18,801$ B. T. U. per minute utilized in the wet chamber.

The total B. T. U. utilized in both chambers, dry and wet, would be 49,090 plus 18,801 or 67,891.

The total effective B. T. U. entering the system is 84,685 and with 67,891 utilized in the drying chambers, we calculate that 80.1 per cent of the heat entering the drying chambers is utilized.

22.2 per cent being utilized in the wet chamber and 57.9 being utilized in the dry chamber.

We note from previous calculations that the heated air going to the drying chambers carries 84,685 B. T. U. per minute or 5,081,100 B. T. U. per hour.

The net B. T. U. per hour from the coal burned is 7,605,360.

The total efficiency of the furnace and air heater is therefore 5,081,100 divided by 7,605,360 = 66.7 per cent.

The combustion gases carry 40,194 B. T. U. per minute or 2,411,640 B. T. U. per hour, or 31.7 per cent of total net B. T. U.

2,411,640 plus 5,081,100 = 7,492,740 B. T. U. accounted for in combustion gases and heated air, leaves 109,627 B. T. U. to be accounted for in furnace losses, etc.

This amounts to 1.6 per cent of total B. T. U.

EVAPORATION CALCULATIONS

The amount of extract sprayed into the dry chamber is 2,104.5 gallons in six hours.

The specific gravity of the extract is 1.223.

Weight per gallon is therefore $1.223 \times 8.34 = 10.20$ pounds.

$2,104.5 \times 10.20 = 21,466$ pounds of extract atomized during test of six hours.

Per cent of solids in extract is 41.14.

$21,466 \times 41.14 = 8,931$ pounds of solids.

$21,466 - 8,931 = 12,535$ pounds of water.

12,535 divided by 360 = 34.8 pounds of water per minute.

Powder recovered in dry chamber 7,767 pounds.

Per cent moisture in powder 5.05.

$7,767 \times .95 = 7,366$ pounds dry extract recovered in dry chamber.

$8,931 - 7,366 = 1,565$ pounds of dry extract carried to the wet chamber during test.

7366 divided by 8931 = 82.47 per cent recovery in dry chamber.

The amount of water in the wet chamber at the commencement of the test was 4416 gallons. The specific gravity was 1.084.

Weight of liquor in chamber was therefore $4416 \times 8.34 \times 1.084 = 39,924$ pounds.

The per cent solids at commencement of test was 19.422.

The weight solids was therefore $39924 \times .19422 = 7759$ pounds.

The wet chamber at the end of test contains 3505 gallons.

The evaporation is therefore 911 gallons.

The specific gravity at end of test is 1.119. The weight of liquor in the chamber is therefore $3505 \times 8.34 \times 1.119 = 32,711$ pounds.

The per cent solids at end of the test is 24.562. The weight of solids is therefore $32,711 \times .24562$ or 8032 pounds.

The dry extract powder which was floating on surface of the liquor in the wet chamber was then dissolved.

The chamber then contained 3605 gallons with a specific gravity of 1.140 and a per cent solids of 27.55.

The weight of liquor in the chamber is then $3605 \times 8.34 \times 1.14 = 34,276$ pounds.

$34,276 \times .2755 = 9443$ pounds.

$9443 - 8032 = 1411$ pounds of dry extract which was carried into wet chamber.

This is equivalent to 235 pounds per hour.

It was estimated that 1565 pounds of solids were carried to the wet chamber during test. Only 1411 pounds were recovered. There is therefore a loss of 154 pounds, or about 1.6 per cent of the total solids in the extract sprayed.

TOTALS

Time of starting test.....	11:40 A.M.
Time of completion.....	5:40 P.M.
Elapsed time.....	6 hours
Coal burned.....	3,812 lb.
Moisture content 2.96.....	101.5 lb.
Net weight dry coal.....	3,710.5 lb.
Ash dry basis 13.3.....	393.5 lb.
Net weight of combustible.....	3,327 lb.
Extract vaporized—gallons.....	2,104.5
Specific gravity of extract.....	1.223
Weight of extract, total.....	21,466 lb.

Percentage solids.....	41.41
Weight of solids contained.....	8,931 lb.
Weight of water.....	12,535
Weight of powdered extract.....	7,767
Per cent moisture.....	5.05
Weight of dry extract recovered.....	7366 lb.
Efficiency shown in ratio of dry extract recovered to total solids in liquid vaporized—7366 divided by 8931.....	82.8%

EFFICIENCIES

FUEL

Efficiency of air heater as shown by ratio of B. T. U. absorbed by air passing through heater, to net B. T. U. available from coal consumed.....	66.7 %
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DRY CHAMBER

Efficiency of evaporation in dry chamber as shown by ratio of B. T. U. accounted for in the evaporation of water from liquid extract, to the B. T. U. given up by the hot air passing through the chamber. ($34.8 \times 987.5 = 34,365$ B. T. U. utilized) (49090 B. T. U. from tem. drop.).....	70.0%
Efficiency as shown by ratio of dry extract produced, to total solids in liquor vaporized.....	82.47
Total of extract accounted for as dry powder and as dissolved in wet chamber.....	98.4
Efficiency as shown by ratio of B. T. U. carried by hot air enter- ing dry chamber to total heat absorbed in vaporizing water in both wet and dry chamber.....	65.2

HOURLY QUANTITIES

Coal per hour as fired, pounds.....	635.3
Coal per hour, dry pounds.....	617.8
Net weight of combustible.....	532.3
Net B. T. U. per hour from coal.....	7,605,360
Cubic feet of heated air handled by fan and discharged into evaporating chambers.....	1,032,300
B. T. U. absorbed by heated air and carried into evaporating chambers.....	6,084,000
Extract atomized, gallons.....	350.75
Extract atomized, pounds.....	3,576
Water evaporated, gallons.....	250.4
Water evaporated, pounds.....	2,088.8
Dry extract, pounds.....	1,277.7

RATIOS

Weight of water evaporated per pound coal as fired.....	3.114
Weight of water evaporated, per pound of coal, dry.....	3.881
Weight of water evaporated, per pound, combustible.....	3.924
Weight of dry extract per pound of coal as fired.....	1.932

The results obtained during the study previously described indicated that a much higher thermal efficiency could be obtained by bringing combustion gases directly into the drying room.

This has since been done with a result as predicted.

There were some faults in construction during this study which account for the carrying of so much dry powder to the wet chamber and the low evaporation in the wet chamber.

The air eddy currents and air leaks which brought the dry powder to the wet chamber have been shut off until almost all the extract is recovered as dry powder.

The spray system in the wet chamber has been made more efficient thus increasing the evaporation and at the same time reducing the quantity of extract carried out with the escaping air.

The figures which have been given show that a chestnut extract, and probably any tannin extract, can be produced as a dry powder by this process at a low cost.

The properties of the dry extract are such as to commend it further.

The dry powder dissolves readily in water, the per cent soluble tannins is slightly higher than in the original extract and the dry powder has no tendency to absorb moisture and become "tacky" on remaining exposed to the air for long periods of time.

Tannin extract as prepared by most of the drying processes tends to absorb moisture and becomes sticky. The extract prepared by this process does not evidence that property at all. The dry powder as obtained, stays perfectly dry, and does not become sticky at all. That is probably to be ascribed to the condition in which the dry powder is obtained. As the moisture evaporates from each of these small particles of liquid sprayed into the heating chamber, a round mass of solid material remains. The water seemingly evaporates from the surface first, from the interior last, and these small round particles as examined under the microscope, show that towards the end of the drying operation, there was a little explosion in the center of the particle, as the moisture on the

interior expanded, so that each one of these particles is a little round globule of solid material with a little crater some place on the surface through which this moisture was expelled. We therefore have a particle at the end of the evaporation which is round but the interior of which is hollow. I don't know just why this change in physical character has changed the nature of the material as regards its absorption of water, but that is evidently true. Extract exposed for long periods of time to a moist atmosphere shows no tendency whatever to become sticky or take up moisture. This method of evaporation, further, can be applied not only to tannin extracts such as were evaporated during this test, but to other materials of a similar nature. The particular points which I thought were of interest in this test were, first, the obtaining of a dry material of this nature which would not absorb moisture, second the rather high percentage of recovery of dry material in the process and third, the low cost of this method of evaporation as compared with the use of either an atmospheric drum dryer or a vacuum drum dryer for such materials as the tannin extracts. (Applause.)

DISCUSSION ON PAPER BY MOORE, SADTLER AND DEBEERS, AND McCORMACK

A MEMBER: With regard to the last paper, I am not quite clear in my understanding of the difference in the method of heating the air at present and when the test as described was made. That is, what change was made in the method of heating?

Mr. McCORMACK: When the plan was first applied, the installation was made seemingly with the idea that it would not do to send the combustion gases directly to the drying chamber, because the carbon dioxide present in the gases, or the combustion particles of carbon in the gas and so forth, might interfere with the qualities of the product. Therefore, the air going to the drying chamber was passed through a series of tubes and the combustion gases were passed outside of these tubes so that the air going to the drying chamber was simply heated as it went to the drying chamber. The change was to cut out these tubes and send the air directly from the furnace to the dry chamber, eliminating the loss which would come from the attempt to transfer heat from combustion gases to air going to the drying chamber.

Mr. DILL: I should like to ask Mr. Moore if he is at liberty to give any details regarding the method of drying of chlorine or sulphur dioxide that he expresses on pages 12 and 13, in which the liquefied gas is sprayed into the moist gas which is to be dried.

Mr. MOORE: It goes into quite a subject. Perhaps I don't know just what point you want. We had a question, for instance, of liquefying SO_2 under a 28-inch vacuum, by cold, requiring refrigerations over 100° below Fahrenheit. It is a problem which is not entirely worked out but we have made great strides on it.

The importance of the successful solution of this problem may be judged when it is figured that there will be a possible saving of about \$2500 a day in the operation of our mills. So it is worth while spending considerable money on working on it.

Now, as this SO_2 comes to us it is wet. We were running it through all sorts of drying tubes and apparatus, to take out this moisture, but changes of conditions might upset your whole operation. Consequently, after trying several drying experiments, we took some of the liquid SO_2 that we had made and atomized it right into a chamber into which the SO_2 passed on its way to the coolers, as it is necessary to have absolutely all the moisture removed before it gets in contact with materials of which your refrigerating apparatus must be made. You have difficulties enough at the low temperatures, to say nothing of the other difficulties of corrosion or filling your condenser tubes with ice, etc. The liquor was sprayed fine though we lost some of it, but it was sprayed right down through the moist gas and fine crystals of snow and SO_2 were carried to the bottom of the chamber. Consequently, we got a dry gas and the dry gas then going through the cold tubes condensed to a liquid without causing further trouble. The same principle can be applied to chlorine, but we have not done as much on chlorine as we have on sulphur dioxide. The others are given more as illustration of what can be done rather than what I have done personally.

Mr. DILL: And the solid parts are precipitated from the moisture.

Mr. MOORE: I don't know what you call the resulting compound but it is precipitated in crystalline scales, not exactly in fine nodules but in fine crystals. I am sorry I did not examine them under a microscope. Of course the excess liquid SO_2 goes also to the bottom and all may be recovered.

Mr. DILL: I was chiefly interested in how you got that precipitated moisture out.

Mr. MOORE: There is only a small amount of moisture present as of course we take out the greater part by the ordinary methods of cooling and condensation. These methods while removing most of the moisture do not remove the moisture sufficiently to prevent corrosion. We did not run long enough continuously to have to solve the problem of removing this snow, but I do not think there would be any trouble.

Dr. ANDREWS: I would like to ask in regard to that, just what the fall of temperature in that gas actually is due to the spraying?

Mr. MOORE: I could not say right off on that subject, but my impression is that it was about 10° F. I would not want to say exactly but not very far from that; I would want to refer to my notes.

Mr. BAER: I want to ask in relation to drying vegetables or fruits by air under pressure or the vacuum process, and where the minimum of decomposition takes place.

Mr. MOORE: I can't answer, I don't know anything about it.

Mr. BAER: You mentioned concentrated coffee and also eggs.

Mr. MOORE: In regard to concentrated coffee, I had something to do with that problem, but unfortunately owing to the conditions under which I did that thing, I couldn't absolutely give it away. The same is true with my work with eggs. I would like to give you some of the information on that, but under the conditions under which I obtained it, I am absolutely debarred from giving any information on the subject.

Mr. BAER: Have you any information as to the relative amount of decomposition by the vacuum process, or air drying?

Mr. MOORE: Nothing that I can give out. The decomposition in some cases I will say is very considerable.

Mr. BAER: More in the dry air under pressure than in the vacuum process?

Mr. MOORE: Why, conditions are different. They cannot be substituted. When you evaporate with dry air you have a cooling effect. When you evaporate in a vacuum you have a heating effect on those parts brought in contact with a hot surface. This is especially true of solids.

If local overheating is the controlling factor you may not be able to use a vacuum as you are liable to have local decomposition.

On the other hand, if local overheating is not the controlling factor, you may use a vacuum.

If, however, local overheating is not the controlling factor but

mechanical difficulties are the controlling factor then air drying may be resorted to. In cases liable to oxidation you must use an inert gas or a vacuum. The choice of these methods all depends on what is the controlling factor.

Mr. BAER: That answers my question, thank you.

Mr. HEMINGWAY: I should like to ask Mr. Moore if he knows anything of the atomizing and drying process that is being offered in New York just now. We are experimenting with it in a small way. I should say the drying chamber, which is constructed of wood, is about 8 feet by 8 feet by 12 feet high. The liquor to be atomized is drawn from a trough attached to the outside of the chamber and running its entire width. This trough is about 10 feet from the floor, which would bring it about 2 feet from the top of the box. The liquor is raised from the trough, passed through the wall of the box and atomized by air under 60 or 70 pounds pressure, through a series of atomizers. On the opposite side of the box, and 2 or 3 feet from the ground, is a wide opening through which hot air is blown, and the strength of the blast is so regulated that the natural upward current of the hot air about offsets the forward blast of the fan. Under properly balanced conditions, the owner of this process claims that there is a pretty close balance within the drying box which permits the powder to fall while the steam passes upwards, and on to a dust-settling chamber, carrying with it only about 1 or 2 per cent of the solid product.

Just before I left the factory the engineer in charge of the process reported to me that there were indications of success, but that so far he had been unable to get his blast hot enough, and, as a consequence, the product was falling to the bottom of the chamber in a sticky condition and not altogether dry. I should like to ask Mr. McCormack also if he knows anything about such a process and if in his experience it has been successful.

Mr. McCORMACK: Why, Mr. Hemingway, you may put your question that way. Of course, if it is a process that is a failure, I know nothing about it. As a matter of fact, I am not familiar with the process, but it seems to me that there are certain fundamentals which are lacking for the successful operation of such a process. For example, we have had no success whatever in the process where the liquor was not atomized into the chamber under high pressure. I neglected to mention that in this extract plan, the liquor is atomized into the chamber at a pressure of about 900 pounds per square inch.

Of course, in any system of this kind, the liquor must not pass completely across your chamber. You must have sufficient space there beyond which the liquor does not go for your particles to settle out. That is one of the difficulties in all of these hot-air drying processes, to get your powder to settle out. In other words, you have to form a certain size particle or it don't settle satisfactorily. You lose too much of it. I don't believe anyone has succeeded in settling such a powder in one chamber. You will note from the report I gave you on this test a considerable quantity of the dry powder is carried over into the second chamber. I don't know of anyone who has succeeded in eliminating that carrying of the powder with air currents. The particles are not entirely uniform in size and, of course, the smaller particles tend to be carried with the air currents, and if some method is not used for the later recovery of those small particles, there will be considerable loss of material in the drying operation.

Mr. BOYLSTON: I would like to ask Mr. McCormack if this process has ever been used with a solvent other than water where there is some object in recovering the solvent, whether it is possible to separate that from the air, or whether it has been tried.

Mr. McCORMACK: It is not, and my judgment would be that it would not be advisable to recover the solvent on such an operation as this.

Mr. DELANEY: I would like to ask Mr. Hemingway whether that is known as the Louge process.

Mr. HEMINGWAY: Yes, sir.

Mr. DELANEY: I can only say that one of my friends has tried to use that method and he has been unsuccessful with it owing to the fact that he can't separate the foam that comes from it.

A MEMBER: I want to ask Mr. McCormack a question. Does not the color of the tanned leather from chestnut wood liquor take a different character from the use of air-drying methods as against the vacuum drum drying?

Mr. McCORMACK: I can answer that very specifically, it does not. Your color is somewhat better from the leather tanned with extract prepared in this way than with extract prepared in the ordinary way. The color of the dry powder is quite a little lighter; that is, take a solution made from the dried powder, it is quite a little lighter in color, at the same gravity than the original extract liquor.

A MEMBER: You don't quite answer my question: I said what is the color of the leather?

Mr. McCORMACK: I answered that first and then later said that also the color of the extract is lighter, as well as the color of the leather.

Mr. HEMINGWAY: I take it in a gathering of this kind, we can talk freely and openly and mention names, as Mr. Delaney did. We ought to be able to, anyhow. Mr. Lough came to our factory, and made quite an impression with the description of his results and that is the reason that we tried out the process. It may not succeed, I don't know; but I think in meetings of this kind that we should fully discuss just such matters as this. It may save us lots of time. Another point is, after Mr. Soule's paper the other night, at least four members, some of whom I had never met before, seemed tremendously interested in this new method of drying and suggested its use for all kinds of different things; in turn giving me many new thoughts for my own work. I hope we shall hear more of Mr. McCormack's results as time goes on.

Mr. McCORMACK: I might say along the line that Mr. Hemingway suggests, that there are certainly a large number of products which will lend attention to drying in this way. Experiments are now being conducted on drying of many different products by such a process as this and there is some experimental work which will have to be done on each product before satisfactory results will be obtained. Size of drying chamber, drying chamber pressure at which you are going to atomize, temperature of the incoming air through your drying chamber and so forth, are factors that will influence the successful operation of the process. Another point which I might mention along the line that Mr. Hemingway brought up is this, that any time that the atomizer delivering the liquor into the drying chamber becomes clogged or pressure changes on the atomizer, or the temperature changes very much in the drying chamber, you run into difficulty. I have seen this particular drying plant all gummed up with extract from the fact that the atomizer instead of atomizing in a perfect spray would have a little groove possibly in one part of the orifice, and the extract would come out in a solid stream instead of broken into a fine spray as it should be. That brings up another feature of this particular atomizer. It is arranged to be self cleaning, that is, if there is anything stopped in the orifice, the pressure goes up at once and when the pressure

increases to a certain point an automatic needle is forced through, cleaning it, and when this is done it is forced back by the pressure on the atomizing side, and the operation proceeds normally.

Mr. DEBEERS: Mr. Moore, to my mind, gave an excellent paper. I can realize the amount of work that was necessary in preparing it.

He mentioned the use of direct evaporation, I mean single or open evaporation, and gave examples of salt brine containing calcium sulphate. We are doing that. A good deal of acetic acid is boiled down in multiple effects. There is one reference made about direct evaporation in a moist vacuum. There is an advantage in the use of a single-effect evaporator in a good many cases, as it permits the use of exhaust steam, whereas open evaporation does not permit the use of exhaust, so that is a practical advantage of a single effect evaporator over an open evaporator. Although the consumption of steam in both cases is the same, it permits the use of waste heat instead of heat that costs money. There is a statement here: "that unfortunately some liquors have such foaming tendencies that no way has yet been discovered to evaporate them without conducting the operation in such a manner as to make this point of vital importance." We have built an evaporator, but have not developed it very much, although it has been used in several places. Mr. McCormack has tried it out and found it to be very good for a very peculiar purpose as regards foaming liquors.

The height of the dome above the tubes in good evaporators is to prevent loss by foaming and things of that sort. But if you try to get over a foaming tendency, which tends to rise, you cannot do it by raising the height of the dome, when it is all solid foam.

Mr. MOORE: You are correct about that, but I mean there is a benefit in the dome up to a certain height.

Mr. DEBEERS: That was not the point.

Mr. MOORE: I was talking about killing the foam.

Mr. DEBEERS: I wanted to be sure that the people understood it, who weren't in the game like you might say we are.

Mr. MOORE: What were some of the others?

Mr. DEBEERS: The matter of the liquor level. You were talking about the advantage of having the liquor level with the salt solution above the tubes, so as to prevent the cutting out effect of salt crystals against the tube. There is no doubt about the logic of that. Where the tube is exposed and where the salt forms in it,

it will cut out the tube. But very often there are other conditions that make it necessary to have the salt form in the tube, aside from the matter of cutting out the tubes. It might be a foamy liquor, having the liquor about the tube. It would, in that case, probably cause a lot of loss by foaming and these things are more important than the cost of the tubes themselves.

Mr. MOORE: In relation to that I want to say a few things. In doing so I shall not mention the name of any manufacturer, as the object of this discussion is not for the purpose of hurting any manufacturer but to bring out information. I have seen evaporators which were constructed for every variable but that of foam. I have seen evaporators which were constructed for every variable but that of tube corrosion and these evaporators gave great trouble on this account. They had not taken into consideration the necessary size of the dome space above the tubes. The dome space in the evaporator as constructed would not allow of the raising of the level of the liquor to a point where the solids precipitated by evaporation ceased to cut off the tubes. In this evaporator the increasing of the dome space would not have obviated the difficulties because by so doing the heating surface originally planned correctly would not be sufficient under this changed condition, provided of course one kept the same difference of exchange. The reason for this will be found in charts 7 and 8, which show the velocities of evaporation of liquors in vertical tubes under the given conditions. If the velocity of liquor inside a tube decreases the conductivity of heat to that liquor decreases. I cannot go into this subject here as it is quite intricate but I refer you to Hausbrand's "Evaporating, Condensing and Cooling Apparatus." Now as these evaporators were not built to stand the increased working pressure which must necessarily follow to get the required increased difference of exchange, you can readily see that neglecting this one factor either required the whole redesign and rebuilding of the evaporator or necessitated the continued running of the evaporator under most expensive and disadvantageous conditions. We have bought an evaporator recently that is causing all kinds of trouble from the cutting out of the tubes due to this very cause. We have raised the level of the liquor above the tubes as far as the apparatus will permit, and we have to a certain extent diminished the cutting out of the tubes, but these evaporators are not constructed with dome space enough to allow us to raise the level to the required extent.

A MEMBER: You ought to have more space.

Mr. MOORE: Had you the required space to raise the liquor you would cut down the capacity as shown by those curves on the velocities, which is a very serious matter,—I know of one loss of \$500,000 on evaporation from one of those causes. I am not at liberty to state how that was written off; that concern wouldn't thank me for telling of that loss of \$500,000.

A MEMBER: We have had a little experience with concentrating weak liquors. We make some rather peculiar ones that are obtained by high temperatures. We had some trouble with foam and we found that we could get away from it by running the liquor in two stages, concentrating from 3° down to 25°, then running it out, and then reconcentrating it forward from 25° to 40°. We have had absolutely no trouble since we started that method and before then we used to have all kinds of difficulty. It was simply a question of having storage capacity, which we had, and so we agreed to run the liquor in two stages.

A MEMBER: I was speaking more of the general question of the foam and how to get away from it.

Mr. MOORE: We will take in the foam proposition. Take a foamy liquor; we carry about 3 inches in the first effect, the foam rises through the hot tubes and the film is evaporated, the liquor returning while the steam goes over to the next effect, where the level may be 4 to 6 inches. In the third effect, it may be 14 inches, in the fourth effect, it may be 3 feet while in the last effect, it may be 7 feet or more in the tube according to the concentration which you get. It is on the same proposition of which you spoke only we don't concentrate in stages. We are dependent on a constant evaporation and not dependent upon evaporation by more or less of an explosion.

A MEMBER: We had that trouble right straight through in each of the effects before, but we no longer have the foamy effect.

Mr. MOORE: I have not done anything with tannin liquors. In this paper, anything I referred to was done as something connected with our own business and most of the results and data obtained from something in our own experience. We are not in the evaporator business anyway.

A MEMBER: I think you ought to be.

Mr. DEBEERS: Referring to the charts about the relative difference in backward flow against forward evaporation. In a good

many cases we have employed backward evaporation. We think it is very advisable and desirable. But I don't think some of the charts are quite fair, for example, the chart refers to liquor 32° F. Well, now, I can't imagine a case in practice where they will have 32° F. If they ever did and they began to feed that into the first effect, why the man in charge of that plant would soon discover that he might just as well heat it up to 120° by putting it through an exhaust line heater in the basement and utilize the waste heat and heat it up even to 320° before it goes into the evaporator. It is a condition that is a theoretical one so that the results based upon that condition are not really fair to show an example of forward evaporation.

Mr. MOORE: This paper does not pretend to go into the matter of the utilization of waste heat. In other words, we realize that is an expert problem, purely of utilization of heat and so this is not a proposition on the utilization of heat, it is a problem of trying to pick out the variables and understand the variables involved, and you have liquor often times at 32° .

Mr. DEBEERS: You will not feed that right into the evaporator.

Mr. MOORE: Well, it is not a question of feeding it direct to the evaporator, when you get to heat utilization. I could write a long paper on heat utilization.

Mr. DEBEERS: The reason I brought that up was that there are some advantages to backward flow. We have to consider the matter of pumps wearing out. They might give all kinds of trouble in pumping backwards, and no allowance was made for steam to be used for pumping.

Mr. MOORE: No allowance was made for steam pumping. The point is right here, in many places, for instance, you have electric energy with which you run the pumps, but as a matter of fact, when you get into the pumping situation, then you are getting into the domain of mechanics, and sometime I will give an article on pumping from effect to effect. That is a mechanical engineering problem which ought to take a paper by itself.

Mr. DEBEERS: That is a situation to do with the condensation of water to run backwards or forwards though.

Mr. MOORE: It is not, though, the major situation, I don't think that is the determining factor. You have never seen a case where the consumption of power will offset some of these larger differences which I have shown here. They are a nuisance as Mr. McCormack

says, but if they are to balance two nuisances against each other, you take the one that is the least nuisance.

Dr. ANDREWS: Mr. Chairman, that matter of pumping the liquor against the vacuum from effect to effect, I would like to have some of these gentlemen here who are real experts on evaporation tell us whether there is any valid reason why the successive effects could not be set at different levels so that the hydrostatic pressure of the liquid from one effect to the other would feed back against the vacuum and so solve the problem. In asking that question I want it to be clearly understood that alone and without their assistance I can see some difficulties in it but it does not appear to me that those difficulties are unsurmountable. I would like to have someone point out some difficulties there that are unsurmountable.

Mr. MOORE: I have not found the chart I was looking for. One reason comes right here, theoretically you could say that each evaporator should be designed with a proper amount of heating surface and that each effect should have a different capacity, or different design according as conditions vary in each. Practically, every evaporator will have to be built alike because you always have the problem of by-passing from one effect to another and the evaporator which might be used for one effect and at a certain level might not function when conditions change, as they do when it becomes necessary to by-pass one or more effects. We have considered the problems of levels but irrespective of those problems the fact that number four effect may be number two effect sometimes, or that you may have a different order or different conditions from what you started with makes this proposition out of the question.

Suppose you reduce ten effects to eight or six effects, the hydrostatic pressure will be all upset. Suppose you have a large number of effects and you want to substitute one effect for another, the same is true. If you have ten effects, you have got to have ten different sizes installed, in other words they are special, you can't build an evaporator in a minute. But suppose in allowing for deteriorations of your materials and so forth, that you can substitute a standard effect which you can have extra for this emergency you don't have all the money tied up in invested but unremunerative capital as would be the case if you had to have each one of ten different effects as an extra as must necessarily follow if you were running effects at their corresponding hydrostatic levels. The idea

of increasing the length of the evaporator at the bottom would be no good at all. It would be necessary in order to carry out the problem stated here to increase the length of the evaporator at the top and then you will have to have your hydrostatic head increase a given amount for a given condition. Now if your specific gravity changes, or your pressures change due to trouble with vacuum pump, drip pump troubles, accumulation of air, air leaks, etc., then you have changed the conditions for which the evaporators were designed and they would then be worthless for the purpose intended. Such an evaporator even if it were successfully worked out for one liquor would be an evil rather than a blessing as it would tend to standardize the prevailing condition in other parts of the plant rather than allow them to make progress by changing conditions and throwing the changed liquor in the hands of the evaporator man to take care of. The only way this could be met is to install pumps. When you do this you have abandoned your proposition of a hydrostatic level and will have had a costly and annoying experience.

Mr. McCORMACK: It might be proper now while we are on this subject of foamy liquors to offer some comments on a Swenson evaporation. In the paper of Mr. deBeers I think he was a little too modest in speaking about the evaporator they built particularly for foaming liquors. I don't know just what he had against me, the first one he built of that type he shoved on me, so I have probably more experience than he has.

One feature which I neglected to mention on this evaporator is the method in construction which enables one very easily and simply to pump the liquor up from the bottom of the evaporator and take it up over the distributing plate which trickles it down over the tubes. In my opinion that is one of the essential features of the evaporator because I have done most of the experimental work on these very evaporators that have been submitted to Mr. deBeers and we find the question of foaming or not foaming is primarily a question of concentration such as Mr. Delaney brought up. It is characteristic of these foamy liquors that they are foamy when they are in dilute solution. My experience has been in single effect. We attempt as soon as possible to establish a certain concentration of liquor in the evaporator. Then we find that the foam disappears entirely. And, as we keep the flow at a certain rate, so as not to decrease our concentration too much, we have been able to handle any liquor that has been submitted to us thus far without

any foaming of the liquor except during this primary concentration, which is only a short period.

Mr. MOORE: I found the chart which I had tried to find a few moments ago. For instance, here is a difference in pressure 89 to 59 pounds, there is 30 pounds pressure, multiply that by $2\frac{3}{10}$ and you can see an increase of 69 feet in the height. Here the next effect is 59 to 35. There is 24, or an increase of 55 feet in the height. I might mention others. If you go on through these charts you can see what is the level of the liquor which must be allowed for by static head and that this added to all the difficulties which are present will make such a proposition impracticable. Mr. deBeers will tell you that the problems of evaporation, of multiple effect evaporation are so complicated that any addition or complication added to what we already have may be disastrous.

Mr. DEBEERS: Speaking about the use of pumps, didn't you have some trouble, Mr. Moore, in your regulation of the liquor level by pumping as against hand control by valves, which goes through normally?

Mr. MOORE: We had all kinds of trouble at first.

Mr. DEBEERS: Until you got your man broken in.

Mr. MOORE: It was not entirely the personal equation of the man, but sometimes you know machines are far more intelligent than men. You can put in such things as regulators and all sorts of things for regulation that men can go and forget. We have solenoids and float valves and all sorts of things to overcome such propositions, and we have absolutely no trouble at all. When I first started on one operation of that sort, I got just eight hours' sleep in a week, and a man came and told the superintendent, "I didn't know Mr. Moore got drunk, he was drunk this morning, staggering home," and they heard of it and sent me up in the woods, where I slept for nearly three days without waking up. But most of the difficulties were caused by the difficulties of the operation. To these were added the difficulties of this pumping operation.

Mr. HEMINGWAY: I have been operating some of Mr. deBeers' evaporators for the last three or four years, and I am glad to say that I have nothing to communicate that may be particularly offensive to him. We installed Mr. deBeers' equipment for the concentration of waste pickle liquors, sulphate of iron, and one minor difficulty took place, which I think should be provided against in later plants for similar work. The trouble lay with the concentrated liquor

pump, working between the last effect and the large crystallizer to which the contents were pumped from time to time. The plant was set up by a man who knew little or nothing about either chemistry or engineering, and, there being no provision on this pump for flushing it out he had not provided one. As a consequence, the moment the aforesaid pump was stopped after passing the first batch to the crystallizer, the liquor in the pump itself and in the lines both sides of the pump chilled and crystallized out solid. After that experience, I not only provided water connections for flushing out the pipes, but also tapped out the liquor end of the pump and added a valve so that the body of the pump itself might be flushed out separately.

I suggest that equipments of this kind will be nearer foolproof if this little matter is given attention.

Mr. McCORMACK: There is one thing Mr. Moore mentioned in his paper which I happen to have a little direct experimental data on, that was the question of heat transmission in evaporator tubes of different compositions. He made the remark, which is certainly correct, that if you take the coefficient of heat transmission and apply it to heat transmission of evaporator tubes, you will shoot wide of the mark. We have some experimental evaporators in which the tubes are interchangeable and I was interested in the determination of the efficiency of heat transmission through various materials. We made some experiments on copper tubes, steel tubes, tin tubes and lead tubes which brought out very clearly the statement that Mr. Moore made. Now, on the copper tubes, our efficiency was 83.4, on the steel tubes 79.5, on tin tubes, 76.7 and on lead tubes 78.8, and this efficiency has nothing to do with the thickness of the tube. For example, the copper tubing was very thin; lead, however, was very thick. After heat has started flowing through the tubes, the metal of which the tubes are composed, seemingly has very little to do with the efficiency.

Mr. DEBEERS: Referring to the charts of Mr. Moore, the concentration of caustic soda was 150 per cent in the sextuple effect.

Mr. MOORE: It can be done in five or six effects.

Mr. DE BEERS: I was going to say that our experience has been that the difference in the matter of the investment sometimes makes it very desirable to do the finishing of the work in the single effect. Your capacity per square foot of tube surface is so much greater

that we really get a better return from our investment by separating the work in two stages. We think so, anyway.

Mr. MOORE: We are doing this on a very large scale in our works, in Berlin, N. H. Lately owing to increasing the production of the plant, this evaporator which has been running for nearly eleven years is not sufficient to evaporate our increased output. We have put in another type of evaporator. At the time I was doing this, I was engaged on a lawsuit and couldn't take a minute off from the immense amount of work which devolved on me in preparing this case. For the additional evaporation, we have bought a multiple effect evaporator from one of the leading evaporator men in the country, which I wish to say is mechanically well designed and so forth, and so on, but certain points are neglected. It is not efficient, however, when it comes to the cost of actual operation. It is not efficient enough. It has tided us over the point when we needed enlargement. From the point of efficiency and repairs and so forth, it is not a good investment, and we shall probably duplicate the original evaporator that we have been using for eleven years, going backwards and using five effects.

Mr. DEBEERS: Isn't it true that most all of your evaporators work by live steam?

Mr. MOORE: No, only one of them works by live steam.

Mr. DEBEERS: Your pressure temperature seems to be rather high on your charts; it looks like live steam work.

Mr. MOORE: Not in this, only in No. 1 effect is live steam used. You cannot have less pressures for caustic soda solutions, besides we don't have any exhaust steam.

Mr. DEBEERS: Most plants that are doing that work have exhaust steam as a waste product.

Mr. MOORE: And they have never gone over two effects and the last operation is carried on in a single effect.

Mr. DEBEERS: We carry it on in two stages and part of the work we do with exhaust because they have it in most places. You have electric power and so forth.

Mr. MOORE: Every time we get any exhaust steam, we dispose of it by putting in more electricity as exhaust steam if properly utilized to 28½ inches vacuum will yield almost as much power as the same weight will yield from 100 pound pressure to exhaust steam.

Mr. DEBEERS: That is a condition in your plant that is peculiar to your plant

Mr. MOORE: Referring to the boiling-points here these are under atmospheric pressure, as 50 per cent caustic soda solution will boil at 305° F. at atmospheric pressure. If you approximately reduce that to 100° by putting it under a much higher vacuum, that would necessitate a 28-inch vacuum and assuming the condition that you had condensed the water of sufficient quantity and cold enough to condense it under 28-inches of vacuum, you would then still have a boiling-point of 205° temperature, which is nearly the temperature of exhaust steam, which means, owing to the loss of heat in transmission in piping, difference of exchange and so forth, that you would have to carry at least a 5 pound pressure on your engines in order to produce 50 per cent caustic and this only with a very large amount of heating surface.

Mr. DEBEERS: I mentioned that at the finish of the work. The work was done with live steam, but the work of evaporation was up to 35° and something that could be done with exhaust.

Mr. MOORE: If you will refer to these charts, you will find with live steam, using the five effect system, putting it backwards, is a most economical proposition.

Mr. DEBEERS: We carry the work to 35° in the multiple effect with exhaust steam because you can do it easily, take up with live steam, and we do that because the plants have the exhaust steam. We would not do it otherwise, simply as an economical proposition because we use it rather than use live steam in a greater number of effects.

Mr. MOORE: I do not know what the strength of your original liquor is, but if it is about 12 per cent it will take about the same amount of live steam to carry your liquor from 35° Bé. to a 50 per cent solution as it would to do your entire evaporation from 12 per cent to 50 per cent backwards so your exhaust steam is wasted.

Mr. DE BEERS: Mr. Moore, you stated that one advantage of backward flow was that the intermediate piping could be uniform in size because of the uniform quantities of vapors. In the way we design piping even if the quantities of the vapors are uniform, our evaporator piping has to be different in size because of the volume of the vapors at different pressures.

Mr. MOORE: I think I have not made myself clear as to this matter. The volume of a given quantity of steam increases as the vacuum increases according to well-known laws, but for forward evaporation you have to increase the size of the piping for the

increased quantity of steam in addition to that necessary for the increased volume due to the increased vacuum. Referring to Chart 17 in forward evaporation you have 600 pounds of steam from first effect and 1400 pounds at 28-inch vacuum from the last effect. In backward evaporation you have 1050 pounds in the first effect and 700 at 28-inch vacuum from the last effect. It will be seen that in the backward flow the pipes vary less from the average size than in the former case and a simple calculation will show that in the former case the diameter of pipe from the last effect has to be 8.5 times the diameter from the second effect, while in the latter case it is only a little over twice the diameter of the second effect with correspondingly less differences in the intermediate effects. If you have only to double the diameter of your pipe instead of multiplying the diameter by eight and one-half it is a simple matter and can be done with advantage when you consider the question of cutting out one or more effects as may be necessary for repairs.

Mr. DEBEERS: I guess I just read from your paper. You said, "another fact to be observed is that in the backward-flow process the intermediate piping can, as a rule, be approximately of uniform size without waste."

Mr. MOORE: Of course, what you actually do in a case like this is that you make your first pipes larger than required by theory. I expected these points to be brought up by professional evaporator men, as I have found from experience that it is very difficult if not impossible to overcome the inertia of the professional evaporator man, and it was this difficulty which forced us to design and build our own evaporators. Furthermore, the paper which you have in your hand is not the paper I have read. There are several errors in the copy before you. In this paper as I have read it, these errors have been corrected and additional matter has been added.

Mr. McCORMACK: One question I would like to ask Mr. Moore, if he has the information and can give it about some of these products that are shown here, for example, the dried eggs and the dried milk, I would like to ask Mr. Moore if he knows anything about the bacteria count of these samples and what means is used to keep them low.

Mr. MOORE: The United States Government assumed that so many bacteria per c.c. was the correct standard for food products and assumed that the standard should be applied to eggs, and they consequently seized a great quantity of eggs from one concern on

account of the high bacteria count. The case hung on for two years, and these eggs which were not fit for consumption were kept for two years. During the process of the law suit, Prof. William T. Sedgwick and several other experts who I need not mention, but equally well known, had hens brought in and let them lay eggs. They made an examination of the freshly laid eggs and found that the bacteriological count was way up in the millions, far higher than the evaporated eggs, and as a result the Court decided that the Government did not even make out a case at all, and the question was, what shall we do with the eggs which were denounced as unfit for feed and yet had been kept for two years. They sold these eggs as good food and it put them in a very unique position. The bacteriological count, however, can be reduced. Now, there are some things I can't tell you about this because I am subject to the restriction which I explained. However, I will say that one drop of chloroform will sterilize quite a large quantity of eggs, at least the pathogenic bacteria will be largely destroyed in that. There are several things which do that. There is another thing. Bacteria usually, if given sufficient time, will die for lack of moisture, and lack of air, and many eggs which have been sampled for bacteria at one time have been found to have less bacteria upon keeping. There is an objection to keeping some kinds of eggs because they will sometimes develop a kind of fishy odor. I don't know just what the cause of that is. A good lot of those things can be eliminated sometimes by adding a drop of chloroform. It is claimed that in testing eggs by the bacteriological count that judgment should be based on the numbers of pathological bacteria present rather than the total numbers of bacteria.

Mr. McCORMACK: Not being handicapped by some of the limitations which Mr. Moore evidently has an account of some of his clients, I probably can add a little to what he said about the bacteria count on eggs. Now, first, Dr. Winslow's experiments on the bacteria count on eggs must have been taken on broken eggs, were they not? I don't see how they could have been taken any other way, and he would have to break the egg before he could count the bacteria.

My experience on the dried eggs are something along this line, that the U. S. Dept. of Agriculture seized thousands of pounds of dried eggs from our Chicago firms on account of their high bacteria count which ran possibly fifty million bacteria per gram of egg.

They objected to the high bacteria count. Now, after working on the problem for a considerable time, we decided it was due to the fact that the hen does not keep her egg laying apparatus in perfect sterilized condition and that most of the bacteria were on the shell of the eggs so that when the eggs were broken, the bacteria got into the eggs. So that we found that it was very easy to reduce the bacteria count on these eggs from fifty million per gram down to five thousand per gram simply by sterilizing the eggs before they were broken.

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O'NEILL, EDMOND

Colton

HANNA, W. C.

Crockett

DUPERU, A. M.

Glendale

DEAN, J. G.

Heroult

CLARK, W. W.

Los Angeles

BARUCH, EDGAR

SCHMIDT, W. A.

THOMSON, H. N.

San Francisco

GOULD, R. A.

Spreckels

BERGH, E. M.

Stanford Univ.

MITCHELL, J. P.

STILLMAN, J. M.

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GRAHAM, W. C.

SHAFOR, R. W.

Rocky Ford

ZITKOWSKIE, H. E.

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Bridgeport

CAREY, T. F.

Cheshire

BASSETT, WM. H.

Naugatuck

ADGATE, M.

DELAWARE

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Wilmington

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REESE, C. L.

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WARE, E.

WHITE, A. H.

WITHROW, JAS. R.

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Savannah

GIBSON, F. I.

ILLINOIS

Belleville

MALINOVSKY, A.

Chicago

CONVERSE, W. A.

DE BEERS, F. M.

GUDEMAN, EDWARD

HAGEDORN, C.

HOSKINS, WM.

LIHME, C. B.

LOWENSTEIN, A.

McCORMACK, H.

PICKARD, GLENN H.

RICHARDSON, WM. D.

SADTLER, P. B.

Chicago Heights

ANDREWS, L. W.

East St. Louis

BROOKS, P. C.

Evanston

BRAGG, E. B.

La Grange

AYER, A. W.

Oak Park

WILLARD, F. W.

Peoria

SCHUELER, J. L.

Rock Island

CHANDLER, A. R.

Robinson

GOMORY, W. L.

Urbana

BARTOW, ED.

PARR, S. W.

INDIANA

Indianapolis

ELDRED, F. R.

JORDAN, H. E.

IOWA

Charles City

HANSEN, L. M.

KANSAS

Arkansas City

PEARSON, C. W.

KENTUCKY

Louisville

WURSTER, O. H.

LOUISIANA

New Orleans

BECNEL, L. A.

BAUER, G. C.

MARYLAND

Baltimore

HOFFMAN, WM. E.

MEADE, R. K.

MILLER, E. B.

VAN HORN, WM. T.

Chevy Chase

MINOR, J. C.

Curtis Bay

MARSHALL, A. E.

MASSACHUSETTS

Boston

CAMPBELL, C. L.
HOWARD, HENRY
SHARPLES, H.
WESTON, R. S.

Cambridge

KALMUS, H. T.
LITTLE, A. D.

Fall River

AUSTIN, H.

Lcominster

JOYCE, C. M.

Lowell

OLNEY, L. A.

Worcester

WILSON, E. D.

MICHIGAN

Detroit

BAIRD, WM. H.
BRAGG, C. T.
CONNER, A. B.
DURFEE, EARL
KIMMEL, H. R.
PLUMB, R. A.
SMITH, M. B.
SUNDSTROM, C.

Fenton

SIMMONS, W. H.

Midland

DOW, H. H.
GRISWOLD, T.
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Wyandotte

TUCKER, E.

MISSOURI

Joplin

SCHAEFFER, J. A.

Kansas City

LUNDTEIGEN, A.

St. Louis

BEBIE, J.
BOYLSTON, A. C.

St. Louis (cont.)

FRERICHS, F. W.
LARKIN, E. H.
MALLINCKRODT, E.
NEWMAN, A. B.
THOMPSON, P. H.
VEILLON, A. A. L.
WOOD, B. G.

NEBRASKA

Omaha

BARR, WM. M.

CROWLEY, C. F.

NEW HAMPSHIRE

Berlin

MOORE, H. K.

NEW JERSEY

Bound Brook

BICKNELL, R. S.
HEMINGWAY, F.

Chrome

PUCKHABER, G. C.

East Orange

MATOS, L. J.
MATTHEWS, J. M.
MYERS, R. E.

Elizabeth

BOOTH, L. M.
GRAY, THOS. T.

Garfield

GESELL, WM. H.

Gloucester City

HOLLAND, WM. R.
MINER, H. S.

Jamesburg

FOERSTERLING, H.

NEW JERSEY—*Continued**Jersey City*

HELLER, H.
ITTNER, M. H.
SIMPSON, ED. H.

Maurer

ALEXANDER, D. B. W.

Millville

BARTON, G. E.

Montclair

ELLIS, CARLETON
WESSON, DAVID

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PROCHAZKA, GEO. A.
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KILMER, F. B.

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PHILIPP, H.
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Phillipsburg

BAKER, J. T.

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JONES, A. B.
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Rahway

KIPPENBERG, H.

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Beechurst, L. I.

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HAHLWEG, G. P.
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PUCKHABER, G. C.
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SIDEBOTTOM, H.
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SMITH, F. P.
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TOCH, M.	HULL, F. A.
TYLER, S. L.	
WAGNER, T. B.	<i>Syracuse</i>
WEISS, J. M.	BOOTH, WM. M.
WHEELER, T. L.	JONES, L. C.
WHITAKER, M. C.	PORTER, J. EDW.
WHITCOMB, L. R.	
WIECHMANN, F. G.	<i>Troy</i>
WOOD, F. J.	MASON, WM. P.
<i>Niagara Falls</i>	<i>Wantagh, L. I.</i>
FULLER, G. P.	SEAMAN, E. H.
HOOKE, A. H.	
KELLOGG, H. W.	<i>White Plains</i>
LIDBURY, F. A.	SMITH, H. E.
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CLARK, WM. M.	POSTE, EMERSON P.
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CROSS, E. O.	
DORSEY, F. M.	<i>Lakewood</i>
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BOWER, WM. H.
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Sinnamahoning

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S. Bethlehem

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DAVOLL, D.

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TEAS, WM. H.

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Exshaw
BECK, ARTHUR G.

Renfrew
GRAY, C. W.

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CAMPBELL, WM. B.
DECEW, J. A.

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VORCE, L. D.
Westmount
MONK, R. H.

CUBA

Cardenas
MEADE, GEO. P.

Cienfuegos
LE BLANC, E. M.

SPAIN

Carrill
LESSNER, CHAS.

CONSTITUTION

ARTICLE I.

NAME.

This organization shall be termed,

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

ARTICLE II.

OBJECTS.

The objects of this organization shall be:

To advance the cause of applied chemical science.

To give the profession of Chemical Engineers such standing before the community as will justify its recognition by Municipal, State, and National authorities in public works.

To raise the professional standard among Chemical Engineers, discouraging and prohibiting unprofessional conduct.

To coöperate with educational institutions for the improvement of the education of the men who are to enter this profession.

To encourage original work in chemical technology.

To promote pleasant acquaintance and social and professional intercourse among its members.

To publish and distribute such papers as shall add to classified knowledge in chemical engineering and shall increase industrial activity.

ARTICLE III

MEMBERSHIP

SECTION 1. (*Qualifications for Membership.*) Membership shall consist of two grades: Active and Junior.

ACTIVE MEMBERSHIP shall require the following preparation and training:

All candidates must be not less than 30 years of age and must be proficient in chemistry and in some branch of engineering as applied to chemical problems, and must at the time of election be engaged actively in work involving the application of chemical principles to the arts. All candidates for admission to this Institute are expected to have *expert knowledge of at least one branch of applied chemistry*, and must fulfill one of the following requirements:

1. Candidates who hold no degree from an approved university or technical school must have had ten years' experience in chemical technology; five being in responsible charge of operations requiring the elaboration of raw materials, the design of machinery involving chemical processes, or the application of chemistry to industry.

2. Candidates who hold the degree of A. B. (Bachelor of Arts) from an approved university or technical school offering a four-year course must have had at least eight years of practical experience as outlined under No. 1.

3. Candidates who hold the degree of Ch. E. (Chemical Engineer), B. S. (Bachelor of Science), in Chemistry or Chemical Engineering, or E. E. (Electrical Engineer), C. E. (Civil Engineer), or M. E. (Mechanical Engineer), or equivalent degrees from an approved university or technical school offering at least a four-year course, must have had at least five years' practical experience as outlined under No. 1.

4. For candidates who in addition hold the degree of Ph. D. (Doctor of Philosophy) or Sc. D. (Doctor of Science) in Chemistry, the number of years required to earn the higher degree may be deducted from the number of years of experience required.

JUNIOR MEMBERSHIP shall require the following preparation and training:

All candidates must be not less than 23 years of age and must be engaged, at the time of election, in some branch of applied chemistry and must fulfill one of the following requirements:

1. Hold the degree of Ch.E. (Chemical Engineer), B.S. (Bachelor of Science) in Chemistry or Chemical Engineering, E.E. (Electrical Engineer), C.E. (Civil Engineer), M.E. (Mechanical Engineer), or equivalent degree from an approved university or technical school offering at least a four years' course.

2. Have had five years' experience in Applied Chemistry.

Junior Members shall have all privileges of the Institute excepting those of voting, holding office, and wearing the emblem or badge of Active Membership. A suitable emblem or badge of Junior Membership as adopted by the Institute may be worn by the Junior Members. When qualified, a Junior Member may apply for Active Membership, but must do so before reaching the age of 35, otherwise his membership shall expire.

Section 2. (*Applications.*) All applications for membership must be made to the Secretary in writing, and shall embody a concise

statement with the dates of the candidate's professional training and experience, and shall be in a form and in such detail as may be prescribed by the Membership Committee. The applicant for Active Membership shall give the names of at least five members to whom he is personally known. The applicant for Junior Membership shall give the names of at least five persons to whom he is personally known, two of whom shall preferably be members of the Institute. Each of these shall be requested by the Secretary to certify to the training, experience, professional attainment, and standing of the applicant. On receiving a favorable report from at least three of these references, the applicant shall be eligible to recommendation by the Membership Committee.

Section 3. (*Election of Members.*) At stated periods the Secretary shall mail to the members a ballot containing a list of all applicants who have been recommended by the Membership Committee. This list shall contain a detailed statement of each applicant's career and the names of the members who have vouched for him. All ballots shall be returned to the Secretary not later than three weeks after the date of issue. The ballots shall be canvassed by the Membership Committee, who shall report to the Council, who shall then declare each applicant elected for whom at least ninety-five per cent. of all ballots cast are in the affirmative. Provided, however, that any member voting in the negative may address a confidential letter to the Council, stating his objections to the candidate with evidence for the charges made. If the Council upon investigation considers such objections valid, they may declare an election void. A rejected candidate may make application again any time after one year. Persons elected to membership shall be notified at once by the Secretary. They must then subscribe to the rules of the Institute.

Section 4. (*Honorary Members.*) As the result of unusual ability and public recognition on the part of the industrial world, a person may, upon nomination of the Council and a vote of the Society at large, be made an Honorary Member, but at no time shall this number exceed five.

Section 5. (*Expulsions.*) For abuse or misuse of the privileges of the Institute or conduct unbecoming a member in the opinion of the Council, a two-thirds vote of the Council may expel any member of the Institute.

Section 6. (*Dues.*) The entrance fee for Active Members shall be \$15.00; Junior Members shall pay no entrance fee; Annual dues

for active members \$15.00, for Junior Members \$10.00. Junior Members, on becoming Active Members, shall pay an entrance fee of \$15.00 less \$1.00 per year for each year of their membership as Junior Members. Provided, however, that no entrance fee shall be exacted until the membership shall reach 200.

Any member may anticipate his dues for life by paying in advance such a sum as would be demanded by any reputable insurance association to yield an annuity equal to the annual dues from the time of the agreement until death. Upon resignation, or expulsion, all money so provided is to become the property of the Institute. Any person joining the Institute after the middle of the fiscal year is required to pay one-half of the dues only for that year. Any person in arrears for three months shall be notified by the Secretary. For non-payment at the expiration of one-half year, a member forfeits the right to vote or to receive the notices of the Association until dues are paid in full. Any member one year or more in arrears of dues may, on vote of the Council, be dropped from the Institute. All members are considered as such unless actual resignations are formally presented and accepted with the full payment of dues. On account of extenuating circumstances, dues may be remitted to any member by a two-thirds vote of the Council.

ARTICLE IV.

OFFICERS.

Section 1. The officers of this Society shall be a President, three Vice-Presidents, a Secretary, a Treasurer, an Auditor, and nine Directors. The officers shall be elected at the annual meeting. The President shall serve one year, the Vice-Presidents for three years each, and the Directors for three years each. The Secretary, Treasurer, and Auditor shall be elected for terms of one year each. At the first annual meeting one Vice-President shall be chosen for one year, one for two years, and one for three years. Three Directors shall be chosen for one year, three for two years, and three for three years. Thereafter, officers shall be chosen annually to serve full terms. The President, Ex-Presidents for the two years succeeding the expiration of their term of office as President, Vice-Presidents, Secretary, Treasurer, and Directors shall constitute the Council of the Institute. The President, Vice-Presidents, and Directors cannot be re-elected within the current twelve months from the expiration of term. The duties of office begin immediately

after election and notification. An acceptance of office must be in writing addressed to the Secretary. Vacancies occurring in any office shall be filled by a majority vote of the Council for the unexpired term. The duties of all officers shall be such as usually pertain to their offices or may be delegated to them by the Council or the Institute.

Section 2. (*Election of Officers.*) After the election at which this Constitution is adopted, the election of officers shall be by letter ballot. The Secretary, at least eight (8) weeks prior to each annual meeting, shall send to every member of the Institute a blank nominating ballot upon which the member may make nominations for the officers and Directors to be elected at the coming annual meeting. The nominating ballot is then to be properly signed and transmitted to the Secretary not later than five (5) weeks prior to the annual meeting. It shall then become the duty of the Secretary to prepare and issue an official ballot upon which shall appear the names of all nominations for office or for Directors which shall have appeared upon at least ten (10) nominating ballots. The official ballots shall be mailed not later than three (3) weeks prior to the annual meeting, one to each member, who shall properly signify on it his choice for the various offices and Directors, and transmit it to the Secretary. At the annual meeting the President shall appoint tellers to whom the Secretary shall deliver all the ballots received by him unopened, and who shall count and announce the vote.

ARTICLE V

COUNCIL

The Council shall have supervision and care of all property of the organization, and shall conduct its affairs according to the Constitution and By-Laws. At each annual meeting it shall present a statement of its proceedings during the year. Eight members of the Council called together by notice from the Secretary shall constitute a quorum, provided, however, that three members may be represented by proxy.

ARTICLE VI.

STANDING COMMITTEES.

The Council shall appoint the following committees:

1. FINANCE.
2. COMMITTEE ON MEETINGS.
3. PUBLICATIONS.

4. MEMBERSHIP.
5. LIBRARY.
6. HOUSE COMMITTEE.

FINANCE COMMITTEE.

The Finance Committee shall have charge of the financial affairs of the Institute. This committee must prepare the budget and approve all expenditures. The Chairman of the Committee may be the Auditor of the Institute.

MEMBERSHIP COMMITTEE.

The Membership Committee shall be constituted of fifteen members, ten of whom may vote by proxy at any meeting. To the Membership Committee all applications for membership shall be referred. It is the duty of this committee to see that no person is admitted to the organization who is not qualified.

COMMITTEE ON MEETINGS.

This committee shall have charge of all meetings of the organization and shall fix dates and places of meeting.

COMMITTEE ON PUBLICATIONS.

This committee shall look after the papers presented to the Institute. If considered expedient, any or all of these papers may be published and distributed to members.

LIBRARY COMMITTEE.

This committee shall have charge of all permanent records, books, papers, pamphlets, etc., and shall obtain and place on file a complete record of all patent literature in reference to chemical engineering.

HOUSE COMMITTEE.

This committee shall look after the social affairs of the Institute, fixing the time and place of entertainments.

ARTICLE VII.

MEETINGS.

The annual meeting of the Association shall be held in December, the exact date to be fixed by the Council.

This Institute shall be governed by its Constitution in conformity with the laws of the United States. All questions shall be decided by majority of votes cast. The Institute shall not be held

responsible for opinions expressed in papers. The name or use of the Institute shall not be tolerated for any commercial purpose.

Upon the adoption of this Constitution officers shall be elected immediately to hold office until the election and installation of their successors.

ARTICLE VIII.

AMENDMENTS TO THE CONSTITUTION.

Any member may propose an amendment by addressing the Secretary. At the first regular meeting thereafter the subject shall be discussed, and if worthy, notice to vote on same shall be posted until the next regular meeting, and written copy of the notice shall be sent to each member. The proposed amendment shall then be discussed in open meeting and can be passed by two-thirds vote of all members of the Institute as the result of letter ballot.

BY-LAWS

ORDER OF BUSINESS.

REGULAR MEETING.

- Reading of minutes of last stated meeting.
- Miscellaneous announcements.
- Reading of papers, discussion, and communications.
- Adjournment.

ANNUAL MEETING.

- Reading of minutes of last stated meeting.
- Miscellaneous announcements.
- Stated business.
- Annual reports.
- Election of officers.
- Address of retiring President, etc.
- Adjournment.

In all questions requiring parliamentary ruling not provided for by the Rules of the Institute, "Robert's Rules of Order" shall be the governing authority.

CODE OF ETHICS

ARTICLE I.

PURPOSE OF THE CODE:

To define the rules of professional conduct and ethics for the members of the Institute.

ARTICLE II.

THE INSTITUTE EXPECTS OF ITS MEMBERS:

1st. That in all their relations, they shall be guided by the highest principles of honor.

2d. The upholding before the public at all times of the dignity of the chemical profession generally and the reputation of the Institute, protecting its members from misrepresentation.

3d. Personal helpfulness and fraternity between its members and toward the profession generally.

4th. The avoidance and discouragement of sensationalism, exaggeration and unwarranted statements. In making the first publication concerning inventions or other chemical advances, they should be made through chemical societies and technical publications.

5th. The refusal to undertake for compensation work which they believe will be unprofitable to clients without first advising said clients as to the improbability of successful results.

6th. The upholding of the principle that unreasonably low charges for professional work tend toward inferior and unreliable

work, especially if such charges are set at a low figure for advertising purposes.

7th. The refusal to lend their names to any questionable enterprise.

8th. Conservatism in all estimates, reports, testimony, etc., especially in connection with the promotion of business enterprises.

9th. That they shall not engage in any occupation which is obviously contrary to law or public welfare.

10th. When a chemical engineer undertakes for others work in connection with which he may make improvements, inventions, plans, designs or other records, he shall preferably enter into a written agreement regarding their ownership. In a case where an agreement is not made or does not cover a point at issue, the following rules shall apply:

a—If a chemical engineer uses information which is not common knowledge or public property, but which he obtains from a client or employer, any results in the form of plans, designs or other records shall not be regarded as his property, but the property of his client or employer.

b—If a chemical engineer uses only his own knowledge or information or data, which by prior publication or otherwise are public property, and obtains no chemical engineering data from a client or employer except performance specifications or routine information, then the results in the form of inventions, plans, designs or other records should be regarded as the property of the engineer and the client or employer should be entitled to their use only in the case for which the engineer was retained.

c—All work and results accomplished by the chemical engineer in the form of inventions, plans, designs or other records, or outside of the field for which a client or employer has retained him, should be regarded as the chemical engineer's property.

d—When a chemical engineer participates in the building of apparatus from designs supplied him by a client, the designs remain the property of the client and should not be duplicated by the engineer nor anyone representing him for others without express permission.

e—Chemical engineering data or information which a chemical engineer obtains from his client or employer or which he

creates as a result of such information must be considered confidential by the engineer; and while he is justified in using such data or information in his own practice as forming part of his professional experience, its publication without express permission is improper.

f—Designs, data, records and notes made by an employee and referring to his employer's work, should be regarded as his employer's property.

g—A client does not acquire any exclusive right to plans or apparatus made or constructed by a consulting chemical engineer except for the specific case for which they were made.

11th. A chemical engineer cannot honorably accept compensation, financial or otherwise, from more than one interested party, without the consent of all parties; and whether consulting, designing, installing or operating, must not accept compensation directly or indirectly from parties dealing with his client or employer.

When called upon to decide on the use of inventions, apparatus, processes, etc., in which he has a financial interest, he should make his status in the matter clearly understood before engagement.

12th. The chemical engineer should endeavor at all times to give credit for work to those who, so far as his knowledge goes, are the real authors of such work.

13th. Undignified, sensational or misleading advertising is not permitted.

14th. Contracts made by chemical engineers should be subject to the Code of Ethics unless otherwise specified.

ARTICLE III.

For the administration of this Code of Ethics, a Committee on Ethics shall be appointed by the president holding office at the time of the adoption of this Code with the approval of the Council, to consist of five members; one appointed for five years, another for four years, another for three years, another for two years, another for one year, and thereafter, the president then holding office shall appoint one member annually to serve for five years and also fill such vacancies as may occur for an unexpired term. All of these members shall be over forty years of age. The Committee shall elect its own chairman. The Committee on Ethics shall investigate all complaints submitted to them bearing upon the professional con-

duct of any member, and after a fair opportunity to be heard has been given to the member involved, shall report its findings to the Council, whose action shall be final.

ARTICLE IV.

AMENDMENTS.

Additions to or modifications of this Code may be made according to Article VIII of the Constitution.

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